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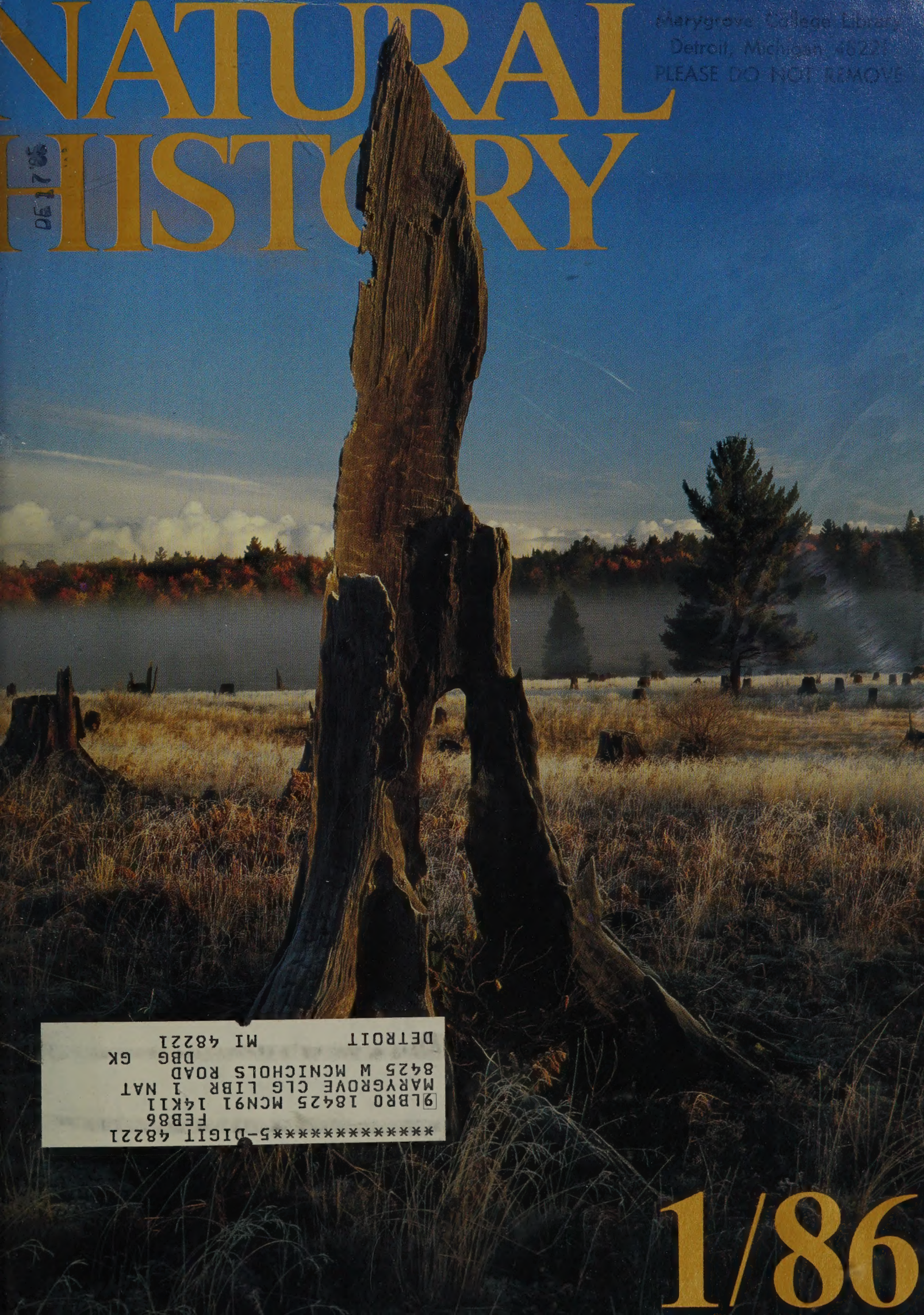

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Vol. 95, No. 1, January 1986
American Museum of Natural History, New York, N.Y.
Robert G. Goelet, President
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10 The Ghost Forest *John Eastman*
For a brief period last century, the great pine forest swarmed with men. Now only tree stumps and memories remain.

18 This View of Life *Stephen Jay Gould*
A Short Way to Big Ends

30 Computer Groupies *Jack Kugelmass*
The current totem in humanity's age-old love affair with the machine

40 White Whales on Holiday *Text and photographs by Fred Bruemmer*
In Arctic inlets, where they were once slaughtered by the thousands, these timid whales now gather for play and procreation.

50 A Matter of Gravity *Photographs by Peggy and Erwin Bauer*
Who knows what evil lurks in the heart of Ponchatoula swamp? The little blue heron knows.

56 Tibet's All-Purpose Beast of Burden *James W. Larrick and Kathy B. Burck*
At 20,000 feet, where simple survival is an ordeal, yaks carry 100-pound loads.

66 Paper Spirits of Mexico *Alan R. Sandstrom*
"It is dangerous . . . to gather information on the pagano-Christian customs of the Indians."

74 Reviews *John R. Alden*
After Christopher Columbus

78 The Living Museum *Marshall Schwartzman*
A Warrior's Last Stance

80 Sky Reporter *Stephen P. Maran*
A Telltale Wobble

84 Celestial Events *Thomas D. Nicholson*
Mars Is the One

88 This Land *Robert H. Mohlenbrock*
Nordhouse Dunes, Michigan

100 The Natural Moment *Art Wolfe*
Striking Courtship

102 A Matter of Taste *Raymond Sokolov*
The Real Thing

106 Authors

Cover: *The fire-scarred stump of a white pine—silent testimony to a great forest—stands in a field in Schoolcraft County, Michigan. Photograph by Robert P. Carr. Story on Page 10.*

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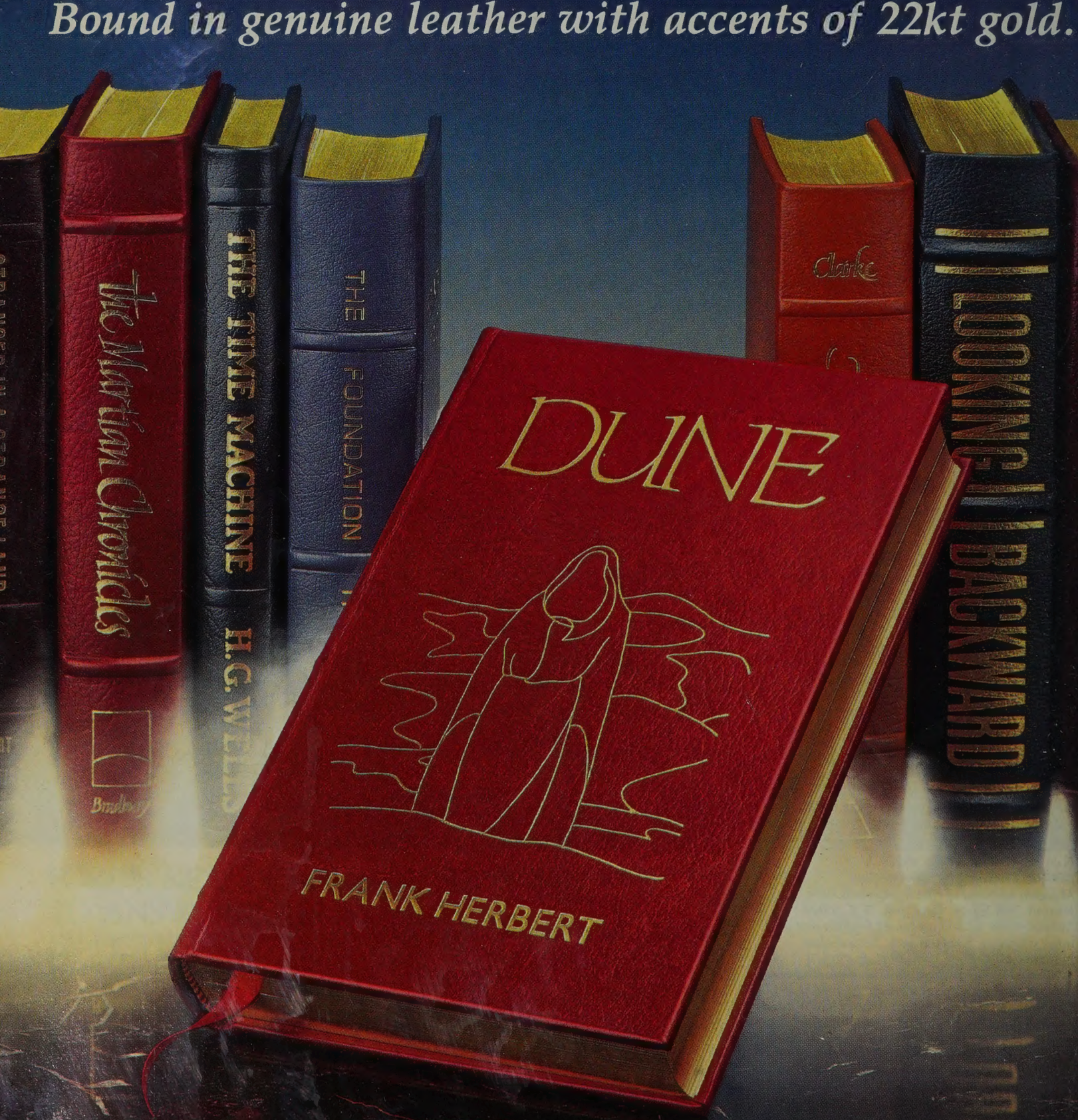

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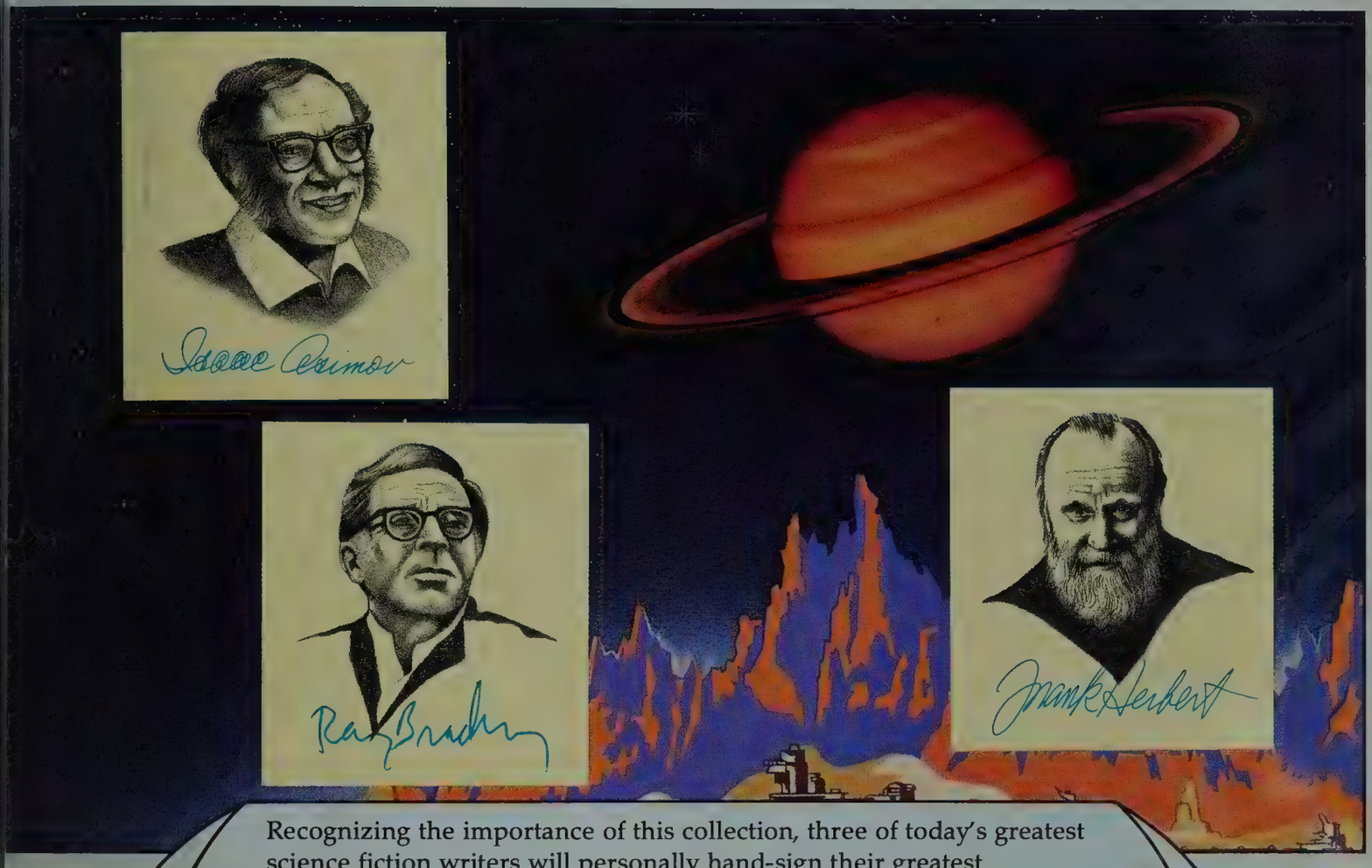

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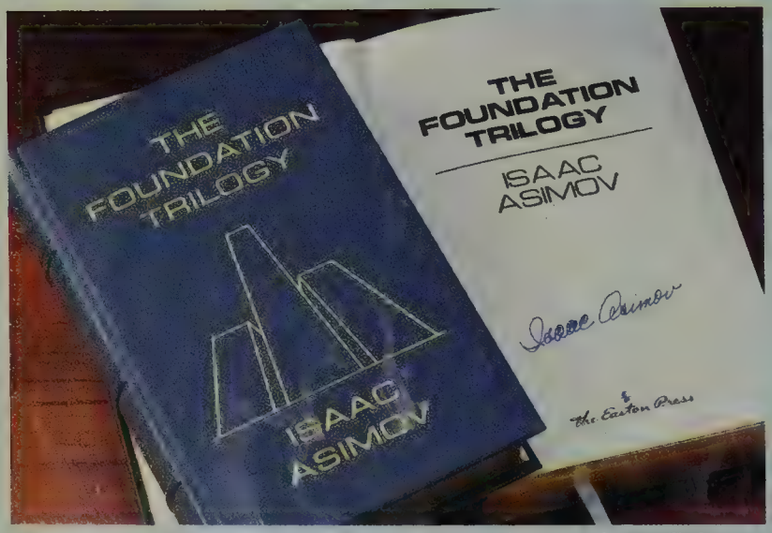

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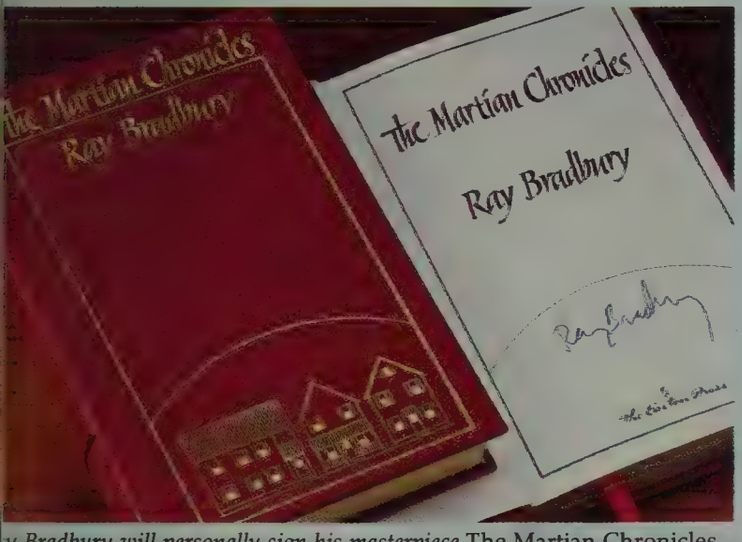

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The Ghost Forest

Nineteenth-century logging left Michigan's vast pine tracts stripped, stumped, and subject to fire

by John Eastman

Up hill and down, extending miles across northern Michigan, the pine stumps endure. They squat in hard-core silence, cracked and ravaged by age, insect, lichen, and fire, eroding like upthrusts of an old geology in a modern sea of bracken fern and aspen. They are time warps in the landscape, relics of the golden age of timber, amputees of an America I never knew. Today they form a ghost forest of sullen carcasses littering the slopes and plains that bridge the inland seas.

Bill's tract of ghost forest, some forty acres of field and scrub, lies on a dirt road that angles about a mile off the Mancelona-Gaylord highway near Michigan's mitten tip. This is moraine country, dumpings left by glacial ice, with high ridges and dips marking the sites of melting during the great continental springtime 10,000 years ago. Past Bill's cabin, the road, now a rocky trail, rises into second-growth beech–maple forest.

Bill's cabin is a stump of sorts itself, a shingle-and-board structure hammered together by Bill and his dad in 1954 over a capped oil well. They intended and used it as a deer hunting shanty, but like so many of us hotshots in our late forties, Bill has lost interest in shooting to kill. He now uses the cabin to host his friends on occasional long weekends.

The ghost forest grows on you only when all the laughter and good fellowship go home. I bunk in by myself for weeks at a time, using the cabin as a base for hiking, scribbling, and cloud watching. True silence would affect one as unbearably as a constant scream, but there is never silence here. Yet the sounds that emerge after the final joke and the last "so long" as the cars roll out are of a type often mistaken for silence. The first day or so alone consists of perceiving the stir of trees, the sounds of insects and birds, familiar languages too easily voiced over by the human larynx. It is like switching from operetta to Gregorian chant. One puts more into listening and seeing; nerves fine tune to different modes, become auditory, sightful.

No living person will ever experience the Michigan pine forest as it was in the

Log drivers on the Muskegon River, 1880s

Muskegon County Museum

Michigan Historical Collections, Bentley Historical Library, University of Michigan

Nineteenth-century lumbering was as disciplined as a military siege.

nineteenth century. This was a landscape so shagged in immense trees that observers could only bring it into focus by means of its own mythology and superhero, Paul Bunyan. The written accounts of persons who actually saw this forest consist of awed understatements, implicit double takes. In another generation or two the story will be wholly legend, its now-obvious, stump-ridden truth only a matter of belief, as are all historical chronicles.

A few protected fragments of this forest survive here and there as living museum specimens. But since a forest community is like a natural lake or prairie—you can't duplicate a chunk of it, you can only represent it—it is all or nothing, and the great pine forest of Michigan has been nothing for almost a century. The pulpwood plantings and Christmas tree lots that currently make much of northern Michigan a vast tree farm are pitiable representations, bearing no more resemblance to the pretimbered landscape than our annual December glut does to peace and good will on earth.

The white and red pine forest began on an east–west line from Saginaw to Lake Michigan and extended virtually unbroken to the Straits of Mackinac and above. Large-scale lumbering began about 1875 and had clear-cut all but small islands of the forest by 1900. The literature and lore of *Pinus strobus,* white pine, the only five-needled pine east of the Rockies, is vast. Thoreau likened its stratified boughs to clouds and each pine to "a great green feather stuck in the ground." The leaves (needles) are almost five inches long, three-sided, and end in a sharp point. Two of its surfaces are white-lined. A pocket magnifier shows what a finger feels in sliding back from the tip, that the needle is minutely toothed. Pine leaves remain green and functional from spring to October of the following year, then turn brown and linger for another year or so before falling to what Aldo Leopold called "the accumulated wisdom" of the duff.

These details form part of a larger anatomy, for pine is the larynx of the wind. No other trees unravel, comb, and disperse moving air so thoroughly. Yet they also seem to concentrate the winds, wringing mosaics of sound from gale weather—voice echos, cries, sobs, conversations, maniacal calls. With the help of only slight imagination, they are receiving stations to which all winds check in, filtering out their loads of B-flats and F minors, processing auditory debris swept from all corners of the sound-bearing world.

Other trails, straight old oil roads, cross and parallel the ridges. Across Bill's unfenced land passes a section of the old railroad bed on which the Shay locomotives and flatcars hauled out the logs. Shovel gangs came before the timber crews, clearing and grading passages through the woods for the temporary rails,

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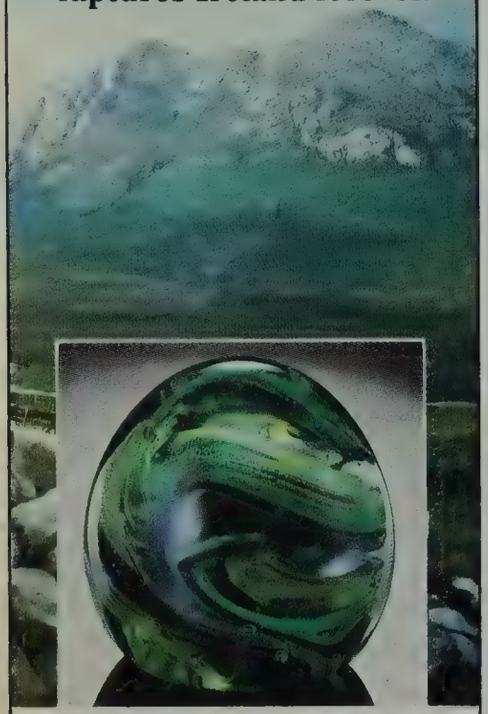

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nough a Shay locomotive could run on ine poles if necessary. These gangs pulled p the rails when the crews lumbered on, eaving the graded trails winding through slum of oozing, fragrant resins. The phemeral railroads enabled year-round ork in the woods rather than winter-only easons when timber could be skidded out n snow.

When timber crews descended on an rea, events moved swiftly. Men teemed nd teamed, surrounding and infiltrating section of forest. Lumbering was an at-ack operation, as thoroughly strategic nd disciplined as a military siege. The orest, suddenly noisy as a factory, warmed with men in a hurry. Harvest ommenced as the first axes bit. Activity urged with the rip of the crosscut, the roan, rush, and slam of the trunks as they ell; the yells, laughter, and cussing of men ungry and tired on the precise schedules f a logger's life. Division of labor was also recise. Sawyers didn't touch axes, and immers kept clear of haulers.

Most of the trees were notched about aist high above the ground, and each of ne cut surfaces seen today, although eeply eroded, represents the straining uscles of two men. Axmen first chopped wedge on the side where they wanted to y the tree. Then, with a crosscut more an six feet long, the sawyer team worked ward the notch from the opposite side, riving wedges behind the cut as they

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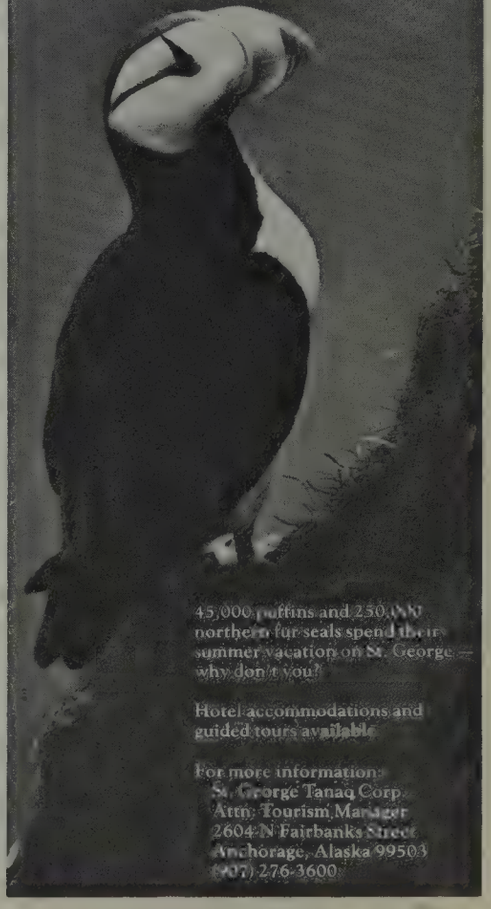

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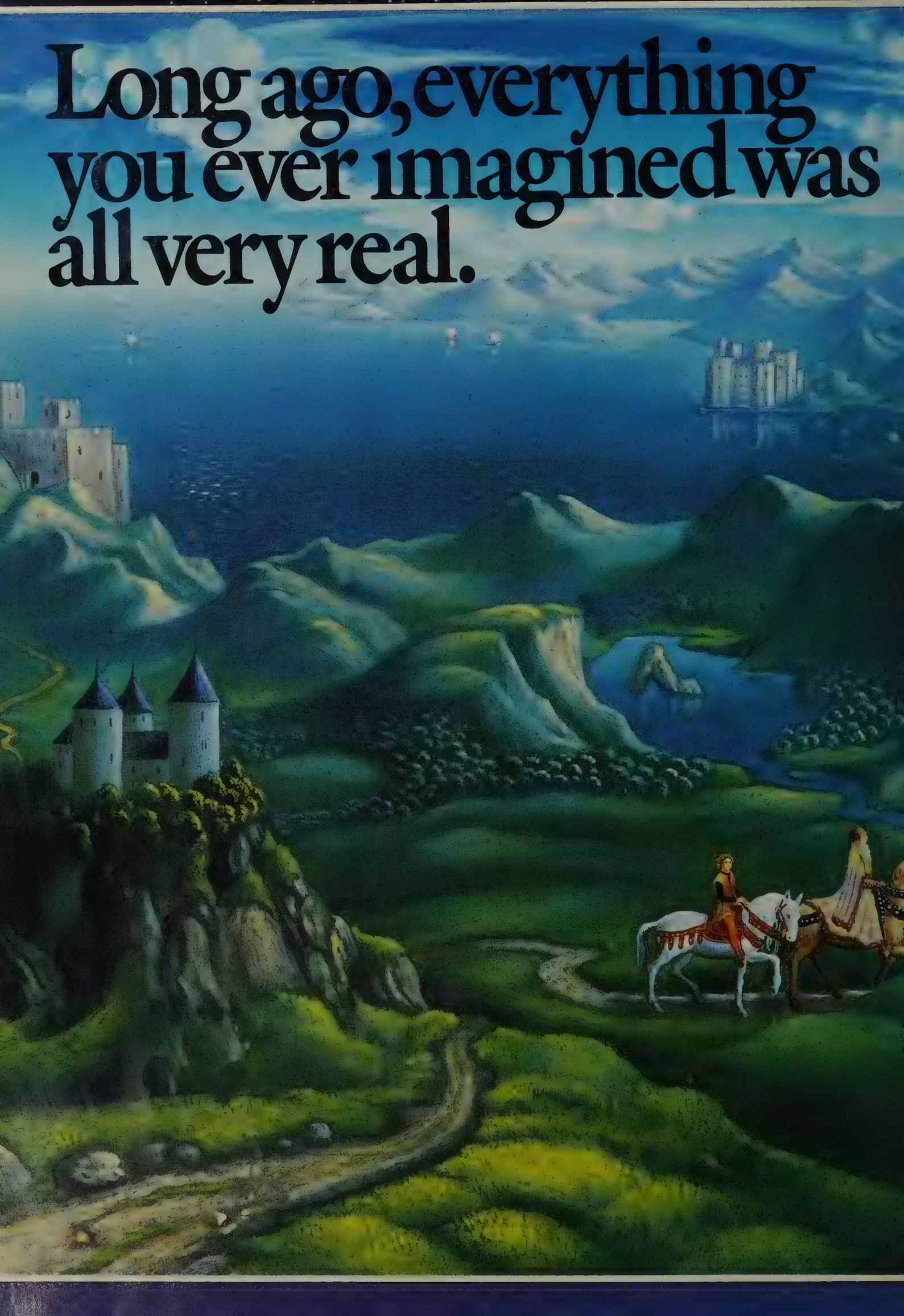
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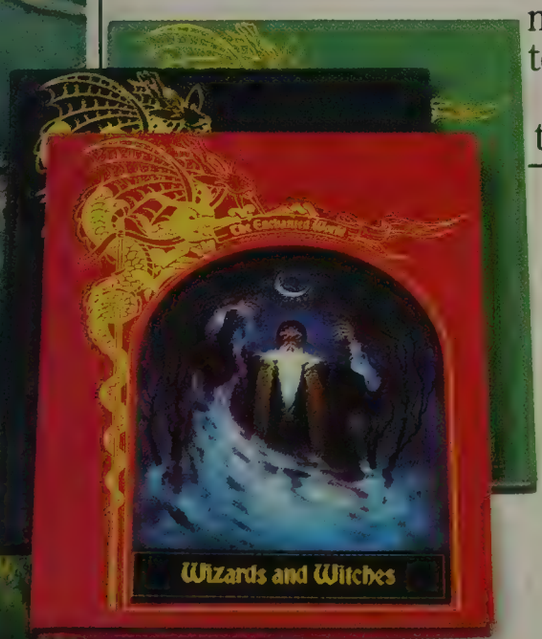

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Muskegon County Museum

An axman and two sawyers flank a tree

progressed. The movements of these men became so ritualized from repetition that the felling of a pine must have been a graceful choreography from the first ax swing to the final gift of the tree to gravity.

Today only the outer shells of the stumps still show remnants of the original cuts. The ax bite is a little lower than the saw cut. You can instantly deduce where the men stood, exactly the direction in which the tree tipped, leaned, and smashed (if everything went right). Loggers preferred to lay a tree on the downhill side, so they usually worked uphill to clear space for later falls. It can all be read in the old surface cuts.

So each stump tells a story. I find it hard to imagine them as ever having lived, as cores that fountained vertical streams upward to the canopy, lifting gallons of groundwater to the sky. Most of the stumps measure from two to three feet across at the cut surface (not including the thickness of long-gone bark). The largest stump near Bill's cabin measures forty-two inches across with a near fourteen-foot circumference, a bulwark of a ruin that shelters a bed of Canada mayflower beneath its cavernous base. A stump of this size means that the tree soared here in the early 1600s or before. The men who brought it down could not have been outfit rookies; old men of the woods climbed the slope for this job, and they probably did it for an audience, showing the youngsters how a real logger takes a tree.

When a pine forest falls, it stays down for longer than a human lifetime. White pine cannot sprout from stumps, and its seed germinates only in the subclimax plant environment prepared by a long sequence of previous stages. Plant ecologists believe that white pine sprouted in the fire-cleared openings of the climax red pine, a two-needled species, as a thro back in the sequence of plant dominanc Lightning most often ignited these ancie fires, disrupting the red pine uniformi and thus patterning the primeval forest mosaics of different plant-growth stage

But fire also wrote the forest's epitap For as the loggers harvest-danced we ward across the continent, a savage caric ture of the old, self-healing fires followe The stereotypical "forest fire," previous unknown to large areas of the Americ landscape, was fed by the massive fu bed, much deeper than any natural win fall, that the loggers themselves had pr pared; in some areas, the slashings of pi tops and branches lay hip deep or high Thus invited, the holocaust came duri the 1890s, not long after the last axm failed to pick up their sticks. Unlike t slow, rejuvenative ground fires that Mic igan forests had always known, this i ferno not only swept but scourged t ground. And subsequent, less infern fires have repeatedly moved through t ghost forest. Why so many of the stum survived is a mystery.

They are, of course, collapsing into t crumpled ground bit by fragment ea year. Their exteriors are stone-hard, f sured shells, bored by insects a splotched with lichens and charr patches that still smear black on finge One theory of why they survive is that t heat of fires caused the preservative resi of the heartwood to migrate outward t ward the sapwood, making the interio vulnerable to decay while "petrifying" t rim. That the exterior shells trap moistu is evident, for most of them are vats full damp, red powder. In the second-grow forest of the slopes, yellow birches oft germinate in these punk vats, which th become pedestals for the living trees. T birch eventually overgrows the stum sending root struts down to the groun and where the underlying stump has c cayed away, a birch remains elevated its prop of thick legs with no middle su port. Thus do the carcasses of one fore raise another entirely different stand fro the original.

So the big forest is gone, but the ancie languages can still be heard. At night sometimes rip apart nearby stumps a drag pieces of them to the firepit near t cabin. The wood seems eager to combu sputtering old greases, pouring an o smoke of resins compounded in the h toric canopy, blazing the hot light of A gusts before my time. In campfires occu the final cremation of the pine empire.

John Eastman is a writer who lives Kalamazoo, Michigan.

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A Short Way to Big Ends

by Stephen Jay Gould

As creatures of convention, we fill our literature and mythology with symbols of harsh treatment meted out to misfits. We may shape, often with considerable violence, the offending objects to our preferred size (the bed of Procrustes); or we may abandon items of potential value (*The Pearl* of Steinbeck's novella) because they bring nothing but trouble in an unsuspecting world.

As a different, but perhaps more common, strategy for the suppression of novelty, we may admit the threatening object to our midst, but provide an enveloping mantle of ordinary garb. Thus, through the centuries, clothing has hidden our copious variety or permitted the dangerously different to dwell among us (the wolf as Red Riding Hood's grandmother). The customs officials of a small West Indian island once reclassified my snails as honorary insects because the government's permits for the export of live animals mentioned only birds, beasts, and bugs.

This kind of cover-up, so often amusing in our daily lives, can be quite dangerous in science, for nothing can stifle originality more effectively than an ordinary mantle placed fully and securely over an extraordinary thing.

I wrote last month about an outstanding example in my own profession. The most exciting of all fossil faunas, the soft-bodied Cambrian invertebrates of the Burgess Shale (about 530 million years old), includes about a dozen creatures with basic anatomy so different from anything living today that we must grant them taxonomic distinction at the highest level of new phyla. Yet C.D. Walcott, the eminent paleontologist who found the fauna during a respite from his "other" job as head of the Smithsonian Institution, managed to suppress this uniqueness by shoehorning every last Burgess organism into a modern group. Moreover, Walcott's numerous publications contain not the slightest hint of any doubt, not a whisper about any possible alternative.

What made Walcott so sure about his interpretation—and so wrong? To resolve this dilemma, we must recognize the larger intellectual puzzle that Walcott faced and understand his hope of finding a partial solution among the Burgess organisms.

Walcott was America's premier geologist of Cambrian strata, rocks from the first period of our adequate fossil record. No expert on Cambrian rocks could avoid the primal dilemma posed by their fossils, a paradox that had led Darwin himself to despair—"the case at present must remain inexplicable; and may be truly urged as a valid argument against the view here entertained" (sixth and last edition of the *Origin of Species,* 1872).

Cambrian seas teemed with life preserved in an abundant fossil record. But when geologists of Darwin and Walcott's day studied rocks of earlier, Precambrian times, they found nothing organic—not a trace of anything potentially ancestral to the diverse assemblages of trilobites, mollusks, brachiopods, and other creatures in Cambrian strata. This geologically abrupt transition from blankness to a rich fauna including representatives of almost every modern phylum has been called, in well-chosen metaphor, the Cambrian exp sion. (Studies that began in the ea 1950s and continue at an accelerati pace today have revealed an extensi Precambrian fossil record, but the pr lem of the Cambrian explosion has n receded, since our more extensive lab has still failed to identify any creature th might serve as a plausible immediate a cestor for the Cambrian faunas. Our lar suite of Precambrian organisms includ bacteria, blue-green algae, other simp creatures, and at the very end of Preca brian times, a single fauna of multicellul animals that may represent an entire separate experiment in complex life, no set of ancestors for the later, and famili creatures of Cambrian seas.)

Where, then, are all the Precambri ancestors—or, if they didn't exist in reco nizable form, how did modern complexi get off to such a fast start? Adam Sed wick and Roderick Murchison, Darwi opponents and Britain's leading experts these early strata, simply argued that t Cambrian explosion represented Goo initial decision to people (or at least invertebrate) his earth. Darwin, sensi the challenge to evolution, admitted:

> If numerous species, belonging to the sa genera or families, have really started in life at once, the fact would be fatal to t theory of evolution through natural sele tion. For the development by this means a group of forms, all of which are descend from some one progenitor, must have be an extremely slow process; and the proge tors must have lived long before their mo fied descendants.

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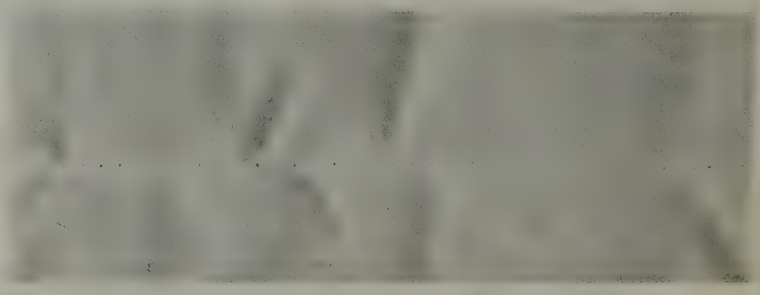

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the absence of Precambrian ancestors have been debated for more than a century—the artifact theory (they were there but the fossil record hasn't preserved them), and the fast-transition theory (they really weren't there, at least as complex invertebrates easily linked to their descendants, and the evolution of modern anatomical plans occurred with a rapidity that threatens our usual ideas about the stately pace of evolutionary change).

Darwin, making his characteristic (and invalid) conflation of leisurely, gradual evolution and change by natural selection, rejected the fast-transition theory out of hand. He insisted that any complex Cambrian creature must have arisen from a lengthy series of Precambrian ancestors *with the same basic anatomy:* " It cannot be doubted that all the Cambrian . . . trilobites are descended from some one crustacean, which must have lived long before the Cambrian age." He then added:

> If the theory [natural selection] be true, it is indisputable that before the lowest Cambrian stratum was deposited long periods elapsed, as long as, or probably far longer than, the whole interval from the Cambrian age to the present day; and that during these vast periods the world swarmed with living creatures.

Instead, Darwin searched for a believable version of the artifact theory, finally proposing that, in Precambrian times, "clear and open oceans may have existed where our continents now stand." Such tracts of uninterrupted water would have received little or no sediments. Hence our current continents, containing all rocks available to our view, rose from an area that accumulated no strata during the crucial span of late Precambrian faunas, while regions of shallow water that did receive Precambrian sediments now lie in our inaccessible oceanic depths.

We can understand Walcott's utterly confident and stubbornly conservative approach to the Burgess animals only in the light of Darwin's dilemma for the Cambrian explosion. Darwin had died in 1882, committed as ever to the artifact theory, and still frustrated that no satisfactory version had ever been presented. Darwin never altered his final assessment, quoted earlier, "the case at present must remain inexplicable . . . ."

Walcott, writing early in our century just a generation after Darwin's death, adhered firmly to Darwin's vision. The theory of evolution, still a tender shoot requiring careful nurture, specified a long and gradual Precambrian approach to anything so complex and varied as the Cambrian fauna. Thus, when Walcott found the Burgess animals and, in one swoop, doubled the diversity of Cambrian anatomies, he feared the unintentional challenge offered to the linchpin of Darwin's resolution—the artifact theory.

Walcott had long maintained a firm commitment to the artifact theory. It provided the keystone for his entire approach to Cambrian life and geology. Walcott never doubted that Cambrian complexity and diversity required a long series of abundant Precambrian ancestors of similar anatomy. He wrote in an early article of 1891:

> That the life in the pre-*Olenellus* sea was large and varied there can be little, if any, doubt. . . . It is only a question of search and favorable conditions to discover it. [*Olenellus,* as then defined, was the oldest Cambrian trilobite, so read Precambrian for pre-*Olenellus.*]

And in one of his last papers (1915):

> When the advanced stage of development of some of the earliest-known forms is considered it seems almost certain that such existed far back in Precambrian time.

Walcott had long defended a particular approach to the artifact theory that a profusion of new Burgess phyla would have undermined. The artifact theory demanded long Precambrian histories for many modern groups in the absence of any Precambrian fossils. Therefore, Precambrian existence would have to be inferred from some aspect of later, recorded history.

Suppose that twenty major groups of invertebrates exist today. What pattern for their history would best support the artifact theory? Walcott sought ammunition for the artifact theory in stability. If the number of basic anatomical designs had not changed throughout life's recorded history, then such stability must surely guide our concept of what came before. Could a system so constant for hundreds of millions of years arise in a geological flash just a moment before? Protracted stability surely implied a very long and stately approach from common ancestry deep in the distant Precambrian mists, not a gigantic burp of creativity from a starting point just below the Cambrian borderline.

We can now understand why Walcott was virtually forced into his conservative account of the Burgess animals—and we note in this story a fine example of how theory exerts its subtle but inevitable hold upon observation. He read his new fauna in the light of thirty previous years spent (largely in frustration) trying to prove the artifact theory as an ultimate tribute to Darwin from a Cambrian geologist. Walcott faced two basic choices for the Burgess. He might, first of all, grant the uniqueness that seems so evident to us today. But a raft of new Burgess phyla would threaten his most cherished belief. If evolution could produce ten new Cambrian phyla and then wipe them out just as quickly (for most never appear in younger rocks), then what about the Cambrian groups that do survive to modern times? Why should they have a long and honorable Precambrian pedigree? Why should they not originate just before the Cambrian, as the fossil record, read literally, seems to indicate? This argument, of course, is a death knell for the artifact theory and a boon to the fast-transition theory.

As a second choice, he could shoehorn all Burgess creatures into modern groups and give the strongest possible boost to the artifact theory. For such a condensation of diversity increased the roster of modern groups already represented right at the start of life's recorded history—and greatly enhanced the apparent stability of major designs through time. Obviously and with both vigor and delight, Walcott chose the second alternative. What does any man do when faced with destruction or affirmation? Walcott extended this second argument as far as he could, claiming that the primary significance for Burgess animals lay in their indirect support for the artifact theory of the Cambrian explosion. He wrote in 1916:

> My own investigations have been mainly in the Cambrian and Precambrian strata and have involved new and somewhat startling discoveries that helped to show how very much earlier life was developed on our planet than we had previously supposed.

In his technical descriptions of Burgess animals, Walcott emphasized over and over again that the more modern groups he could identify in the Burgess, the more confidence he gained in long Precambrian histories—despite a continuing, total absence of evidence. When he thought he had identified members of each modern crustacean group in the Burgess he wrote

> The Cambrian crustacean fauna suggests that five main lines or stems . . . were in existence at the beginning of Cambrian time, and all of them had already had their inception in . . . the period of Precambrian marine sedimentation. . . . The five subclasses are represented as having had a long line of crustacean ancestors, a view that if correct would manifestly necessitate a prolonged Precambrian period for the development of the crustacean fauna now found in the Burgess shale.

And, after hiding almost every interesting Burgess oddball in the Annelida (segmented worms), he concluded that "the

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annelids go to prove that the Cambrian fauna was highly developed and differentiated in Precambrian time."

But Walcott approached the artifact theory from both geological directions—down from the Cambrian, as discussed, and up from the Precambrian—and his argument about the Precambrian has become, in the typically perverse manner of our textbook histories, his most enduring legacy. (Most textbooks contain a traditional, almost mandatory, two- to three-page introductory section on the history of their discipline. These travesties of scholarship dismiss the fine thinkers of our past with two-liners about some error, usually misinterpreted, that show how stupid they were and how enlightened we have become.)

C. D. Walcott was a fine paleontologist and able administrator of the nation's biggest museum. He never obtained a college degree but parlayed his enthusiasm for fossils into several positions at the pinnacle of American science. He worked with Powell in the Grand Canyon, later headed the U.S. Geological Survey, and finally the Smithsonian Institution. Yet ask any student of geology about Walcott, and if you get any response at all, you will probably hear: "Oh yeah, that doofus who invented the nonexistent Lipalian interval to explain the Cambrian explosion."

However, with the preceding discussion of the Burgess and the artifact theory in mind, I think we can finally understand the story of the Lipalian interval properly—and recognize Walcott's proposal as a reasonable, if outstandingly wrong, inference within his general commitments.

The artifact theory was a central necessity in Walcott's scientific perspective. He made an inference from the Burgess, but he needed a more direct argument from the Precambrian. Where had all the Precambrian animals gone? Other ideas included a universal metamorphism (or alteration of rocks by heat and pressure), which had destroyed all Precambrian fossils, and an absence of fossilizable hard parts among Precambrian creatures. Walcott rejected the metamorphism theory because he had found so many unaltered Precambrian rocks and argued that the hard-part theory, while probably true, could not explain the entire phenomenon.

Walcott was, primarily, a field geologist specializing in Cambrian rocks. Following the proclivities of any field man, he approached his growing interest in the problem of the Cambrian explosion in the obvious way—he decided to search the latest Precambrian rocks for the elusive ancestors of Cambrian fossils. He worked for many years in the western United States, the Canadian Rockies (where he discovered the Burgess), and in China, but he found no Precambrian fossils. From the standpoint of this frustration, he tried to reconstruct the geological and topographic history of the late Precambrian earth.

Walcott eventually reached a conclusion opposite to Darwin's speculation but in the same tradition—the rocks that might have housed abundant Precambrian fossils just aren't accessible to us. Darwin had suggested a vast Precambrian ocean with no continents nearby to serve as a source of sediments. Walcott argued that the late Precambrian was a time of uplift and mountain building, with continents far more extensive than today. Since life, according to Walcott and others, had evolved in the oceans and not yet colonized land or fresh waters, these vast Precambrian continents permitted no marine sedimentation in areas now accessible to us. (Walcott wrote long before the era of continental drift and never doubted the permanent position of continents. Thus, today's accessible places for geological observation are the centers of more extensive Precambrian continents—areas devoid of late Precambrian marine sediments. Appropriate sediments might lie under miles of deep ocean, but no technology then existed to recover or even to sample such potential treasures.)

The infamous "Lipalian interval" was Walcott's name for this time of Precambrian nondeposition. As a gap more portentous than anything later devised by Mr. Nixon and Ms. Woods, Walcott proposed a worldwide break in marine sedimentation near continents just during the critical interval of extensive Precambrian ancestry for modern groups. In a famous address to the 11th International Geological Congress, meeting in Stockholm on August 18, 1910, he stated:

> I have for the past 18 years watched the geological and paleontological evidence that might aid in solving the problem of Precambrian life. The great series of Cambrian and Precambrian strata in eastern North America from Alabama to Labrador; in western North America from Nevada and California far into Alberta and British Columbia, and also in China, have been studied and searched for evidences of life until the conclusion had gradually been forced upon one that on the North American continent we have no known Precambrian *marine* deposits containing traces of organic remains, and that the abrupt appearance of the Cambrian fauna results from geological and not from biotic conditions. . . . In a word, the thought is that the Algonkian [late Precambrian] period . . . was a period of continental elevation and largely terrigenous sedimentation in non-marine bodies of water, also a period of deposition by aerial and stream processes over considerable areas.

"Lipalian," he added,

> is proposed for the era of unknown marine sedimentation. . . . The apparently abrupt appearance of the lower Cambrian fauna is . . . to be explained by the absence near our present land area of the sediments, and hence the faunas of the Lipalian period.

Walcott's explanation may sound forced and ad hoc. It was surely born of frustration, rather than the pleasure of discovery. I hope I have shown, however, that the nonexistent Lipalian was not a fool's rationalization, as usually presented in our textbooks, but a credible synthesis of geological evidence in the context of a vexatious dilemma. If Walcott deserves any brickbats, direct them at his failure to consider any alternative to his favored way of thinking about the artifact theory—and at his false assumption, imposed by the old bias of gradualism, that equated evolution itself with long sequences of ancestral continuity for any complex creature. For, even if the nonexistent Lipalian represented a credible synthesis of geological information, it rested—as Walcott knew only too well—upon the most treacherous kind of argument that a scientist can ever use: negative evidence. Walcott admitted: "I fully realize that the conclusions above outlined are based primarily on the absence of a marine fauna in Algonkian rocks."

And, as so often happens in the face of negative evidence, the earth eventually responded, offering to later geologists abundant late Precambrian marine sediments—still with no fossils of complex invertebrates. The Lipalian interval ended up on the trash heap of history.

Why, then, do I bother to tell this old story at all? I do not proceed from antiquarian interest alone but have resurrected Walcott's Lipalian because he based both his particular theory and his general approach upon a deep and interesting error of reasoning that still plagues us. The story of Walcott's error is instructive for our times, not a cardboard homily about superstition and inflexibility.

I have been keeping an informal tally for many years and have reached the conclusion that most interesting errors in the history of science reflect just a few common fallacies of reasoning. My primary candidate must be the confusion of correlation with causality. The universe is chock full of spurious correlations. To choose the most obvious example, most processes are going somewhere, either increasing or decreasing. Everything that is

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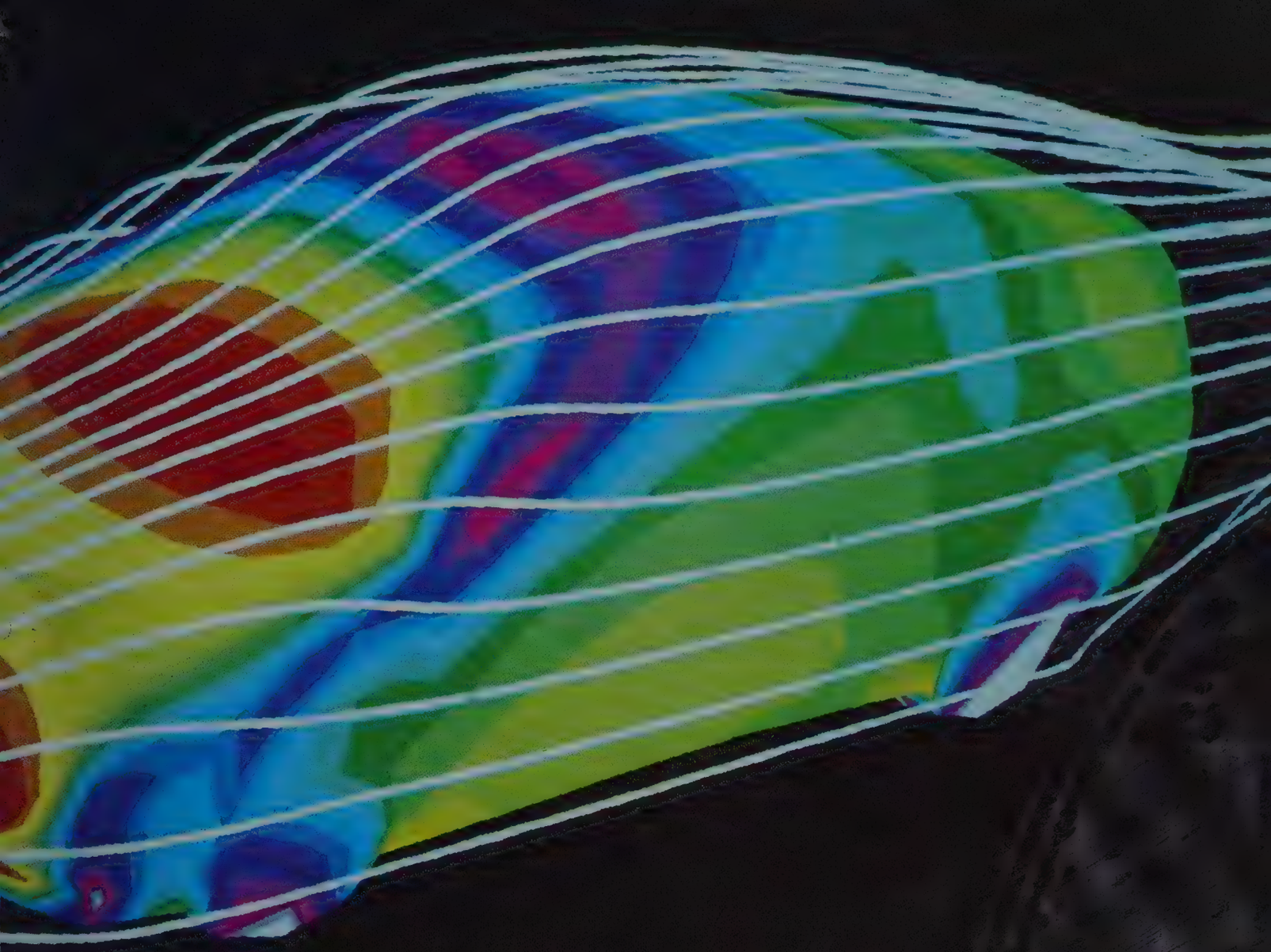

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waxing—the price of bread, the age of the earth, the frequency of terrorist attacks—correlates strongly, but only a fool would use the common increase as evidence for a direct causal relationship. Yet when the processes are not so obviously different as those cited above, we often make the false inference and advocate a causal link from the correlation alone.

My second candidate—Walcott's error—is a spinoff from the problem of correlation and cause: the assumption that a big difference demands a long period of time for its slow development. The larger the effect, in this fallacy, the longer the time for its origin. This line of reasoning would work only if we inhabited a bald (and uninteresting) world filled with objects of no vibrancy or internal structure—lumps of inert matter that simply respond to the force and duration of an external push. In such a world, I suppose, a big difference between two lumps descended from a common ancestral lump would imply either a major force or a smaller force applied for a very long time.

But natural objects are wondrously complex and recalcitrant. The more intricate they grow, the more they become subject to quirky shifts of a magnitude not always predictable from the size or duration of the causal input. A tiny nudge applied to an inert lump may budge it only a small and predictable amount, but exert a small force on the San Andreas fault at a crucial moment or give a human brain just one increment of information at a time of instability, and watch out. We have an intuitive feel for this property of complex systems, for we have enshrined it in our metaphors—the straw that broke the camel's back, the kingdom lost for want of a horseshoe nail. I would argue that the most fascinating property of our complex world as we find it—and the chief joy of those historical sciences that deal directly with nature's intricacy—lies in this very failure to find a simple relationship between intensity of immediate cause and observed outcome. Small inputs, channeled through complex systems with meaningful histories, may engender large and unexpected results. Complex objects push back; they may augment or amplify a causal input or direct it to unexpected results.

Yet evolutionists have often forgotten this most essential property that evolution itself grants to organisms—and have made the false equation between magnitude of difference and time since common ancestry. In particular, since Darwinian evolution, as usually conceived, is a small force at any one moment, leading to great effect only by accumulation in the fullness of time, we may appreciate Walcott's commitment. Cambrian organisms are enormously complex and different. Walcott never doubted that their common ancestor must be sought way back in the Precambrian, while a long sequence of creatures, with anatomies increasingly more like Cambrian forms, must have evolved throughout the Precambrian.

The alternative, the fast-transition theory, does not appeal to miracle or truly instantaneous appearance. It does not advocate an origin of life near the Cambrian boundary, and it does not propose a transformation in one generation from amoeba to invertebrate. It only asks us to appreciate the principle that large changes may take little time because complex systems can respond rapidly to small inputs at crucial intervals.

I do not doubt (indeed we know from direct evidence) that ancestors of Cambrian creatures had a long Precambrian history. But why assume, as the artifact theory proposes, that these ancestors looked like their Cambrian descendants throughout their slow and steady late Precambrian transformation. Why should Cambrian trilobites imply Precambrian arthropods with segmented bodies and paired appendages; and Cambrian brachiopods, Precambrian shelly creatures with two complex valves. The transition to Cambrian anatomical complexity may have been a geologically rapid, late Precambrian event, spanning perhaps ten million years (a decent chunk of time, after all)—a tiny temporal postscript, relatively speaking, to Precambrian billions. Negative evidence remains dangerous, but in a century since Walcott began his work, we have found copious evidence of Precambrian life distributed throughout the world, but no fossils of complex invertebrates belonging to modern groups—while the proper status of many Burgess organisms as unique anatomical designs surely suggests that major experiments in form can wax and wane in episodic, rather than stately, fashion.

Nonetheless, Walcott's error of equating big difference with vast time is no fossil of reasoning. Professionals continue to make the same mistake, and this classic fallacy channels our thinking away from interesting and potentially fruitful alternatives. The Cambrian explosion remains a common field for this error. At the first North American Paleontological Convention in 1969, J. Wyatt Durham, world's expert on the diverse Cambrian echinoderms, tried to infer the duration of Precambrian ancestry from the complexity of Cambrian fossils. He followed Walcott's tradition exactly:

> The diversity of organization present in the early and middle Cambrian indicates that the ancestral stock must have existed before the beginning of the Cambrian; if the rates of evolution were at all comparable to those of subsequent time, the ancestry of the echinoderms must extend well back into the Precambrian.

Durham estimated that 100 to 500 species, stacked end to end, might gradually transform a common ancestor (not a single cell, but already a complex creature bearing the shared characters of all later descendants) to a Cambrian result. Estimating the average duration of a species at 6 million years, he first calculated 500 million to 3 billion years before the Cambrian for the common ancestor of echinoderms. But Durham recognized this estimate as too large, for 3 billion years is close to the origin of life itself, and he only sought a common ancestor for echinoderms. So he revised his average species duration downward to the minimum of a million years and accepted 500 million before the Cambrian as a best estimate of common ancestry.

Durham then tried to link the echinoderms with other related phyla (including us vertebrates) and doubled his estimate to one billion years for the common ancestry of this major limb on life's tree—a comfortable middle position for a reading of life's history as gradual ascent:

> The ancestor . . . appeared slightly over a billion years before the beginning of the Cambrian, about half way along the "ladder of life" subsequent to the first known appearance of organisms.

Quite a long time for no recorded evidence! (Remember that Durham's common ancestor shares the defining traits of these related phyla and should therefore be easily recognized for what it will become. It is not an amoebalike form waiting for a final moment of accelerated glory.)

Durham's specific fallacy is easy to locate. He piled species one on top of the other in a ladder of ascent, not permitting any new form to arise until its immediate ancestor had run a complete course. But evolution occurs more often by splitting of lineages than by transformation. Perhaps we do need 500 species to get from common ancestor to Cambrian echinoderm. But number 379 does not have to wait until 378 finishes a full life of gradual change toward its descendant; 379 may branch off just after the origin of 378, with 380 splitting soon thereafter—and all three then coexisting or competing. In a branching bush, 500 species may arise with dispatch. But Durham's general fal-

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lacy is our old friend—the assumption that big differences must record long times of steady transformation.

To choose a final example from the other end of geological time, and to illustrate the generality of this logical fallacy with an example maximally removed from Walcott's case but perhaps even more immediately important to us, consider the old issue of when our human lineage diverged from its last point of common ancestry with apes (represented today by our closest relatives, chimps and gorillas).

Genetic similarity at the biochemical level indicates a recent time of divergence, some five or so million years ago (see my column of April 1985 for why such data provide good estimates that avoid the fallacy discussed in this essay). Nonetheless, Charles Oxnard, a skilled English anatomist now at the University of Southern California, has resurrected the older idea of much longer independence for our lineage (see his book *The Order of Man,* Yale University Press, 1984).

Oxnard is our leading expert on the quantitative study of skeletons. He has used the techniques of multivariate analysis—a set of statistical tools, forming the basis of my own technical work as well, that can integrate large suites of measurements and extract general estimates of similarity and difference from all measures considered together. Oxnard has spent years studying the australopithecines, the group of African hominids considered by all experts to be our closest genealogical cousins (probably our ancestors as well). Oxnard has argued in several books and articles that australopithecines are anatomically more different from us than other experts imagine. He views them as bipedal like us, but also capable of motion with all fours (probably for climbing) in a manner "far more sophisticated than that of which any human is capable." In short, he sees australopithecines as uniquely different from apes and humans, not as imperfect people on the way up.

So far so good. Perhaps Oxnard is right about his anatomical and functional claims (I do not have the expertise to judge). But I can criticize the fallacious inference he then draws from his multivariate measures of anatomical distance—for it is the same error that Walcott and Durham made for the Precambrian. Oxnard assumes that he can make an inference about time of ancestry from extent of anatomical difference. Since australopithecines are, in his view, so much more unlike us than previously allowed, but still our genealogical cousins, our divergence from them must be more ancient than convention dictates. The still earlier division of ape and human lineages must then be pushed even further back—well beyond the five million years of biochemical data.

From this longer period of human separation, Oxnard draws a string of radical implications. Perhaps humans did evolve from ramapithecines (a group of 10- to 15-million-year-old apes, once viewed as promising ancestors before biochemistry suggested the earlier date, but now linked by good anatomical evidence with orangutans, not with apes nearest to us). Perhaps the human lineage split in Asia after all (as accepted for so long before African discoveries toppled this old claim).

Most importantly, Oxnard then revives the oldest hope of the ancient search for ways to proclaim humans as unique and apart, despite continual assaults from so many sciences against this deepest of all human wishes. If, he argues, humans have been separate from apes for many more million years than biochemistry will allow, then our minds are not in thrall to an animal heritage. We have been separate long enough to shape our brains, and our souls, in our own special way:

> Rather than being a thin veneer, human psycho-social characteristics . . . may in actuality be an enormously thick, complex psycho-social sludge overlying what is, in comparison, only a very thin sliver of prior animal behavior.

I appreciate the noble sentiment and accept the extent of mental difference between us and them—for much as I have campaigned to incorporate us properly within nature, I cannot deny that our leap in conceptual ability is the most portentous and startling evolutionary invention ever introduced on the surface of our earth (our brain is surely the first biological structure with power to destroy the entire tree that nurtured its origin). But, to recall Walcott's error, this remarkable difference between us and them need not record an extended time of evolutionary independence—big effects do not imply long times.

No organ is so intricate and full of potential as the human brain. No structure in all biology is a better candidate for radical outputs from small inputs. No object in all nature is so potentially free from the correlation that dull and simple lumps of stuff may show between time (or strength) of cause and magnitude of effect. The "proper study of mankind" resides in the joy and frustration of this complexity.

Stephen Jay Gould teaches biology, geology, and the history of science at Harvard University.

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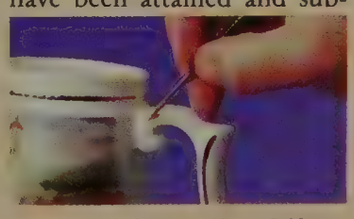

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Computer Groupies

By sharing information, computer users learn to cope with humanity's latest invention

by Jack Kugelmass

Joe King is an expert on computer software although he has had almost no formal training in the new technology. His first contact with computers came when he worked for a large corporation that started using data processing, but his passion for them developed later, when he needed one for his own publishing and consulting business. He settled on the Kaypro, a workhorse machine favored by noncorporate types, particularly writers (it's inexpensive and comes complete with word-processing software). Initially, King was able to handle problems he encountered using the machine by calling the manufacturer in California. The company was helpful, but it couldn't always answer questions relating to software. In the winter of 1982, King and about ten fellow Kaypro owners in the New York area began to meet each month under the auspices of the New York Amateur Computer Club. Most in the Kaypro group were at a fairly elementary level, although a few were professionals who could delve into the machinery and address complex questions. Today there are several hundred dues-paying members, a modem-operated bulletin board, and a newsletter.

Like tens of other first-time attendees at one of the group's meetings, I handed over $12 in dues, attracted less by the annual subscription to the newsletter than by the free black mug with the Kaypro logo that was offered as an incentive for joining that evening. For many new members, that free mug can turn out to be expensive, because they are overwhelmed by the technical banter and do not return after the first meeting. But others get hooked because participation offers the opportunity to master something that has become the current totem in humanity's age-old love affair with the machine.

To the uninitiated, the monthly meetings seem like the ultimate trivia game. The players are of various ages and both sexes, although men in their thirties and forties predominate, and the questions are invented by experts and novices alike. The action usually takes place in an auditorium or university lecture hall (smaller computer groups can meet almost anywhere, from a business office to a private living room). The rules are simple. Someone asks a question, someone else attempts an answer. There are no points, although reputations are made by the frequency and accuracy of the responses. A woman is having trouble with her printer; George suggests she try a different type of ribbon. The chairman recommends that she see George "at the break," the twenty-minute interval between the general question-and-answer period and the subsequent division into smaller special interest groups, or "SIGs." The woman insists the ribbon is not the problem. The chairman advises her *not* to see George at the break. A man explains that he is having trouble with his keyboard: Can he buy a new one The answer is yes, but he receives anothe suggestion: "Open the keyboard and us cotton and alcohol to clean off the connec tors. It's a lot cheaper than buying a ne one and just as effective."

Whereas the New York Kaypro use group includes many men and wome with no prior experience with computer the parent New York Amateur Compute Club (NYACC) caters to those with mor technical interests. Here the majority o participants are male. Founded in 197 NYACC is the second-oldest compute group in the United States (the Hom Brew Computer Club, on the West Coas is slightly older). In addition to the usua questions and answers, NYACC meeting regularly feature guest lecturers. At on meeting I attended, a member of th group, a bank executive, spoke about ho to build an IBM "clone"—a non-IBM computer that can run all the program produced for IBM machines. He devote

Photographs by Jack Kugelma

Unofficial vendors occupy the parking lot at a computer show in New Jersey.

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much of his talk to anecdotes about hunting down parts, like three-millimeter screws to install disk drives. "How long did it take to build the clone?" one member asked. "You can do it within an hour," he replied cheerily, apparently forgetting the 10,000 three-millimeter screws he had been obliged to buy, and the time he had spent looking for a wholesaler. "All you need is a screwdriver—you don't even need a soldering iron. And thirty minutes of that one hour was spent looking for my glasses."

Finding and fitting parts is one of the satisfactions for those club members interested in building their own equipment. This past year the Associated Computer Group of New Jersey held its tenth annual Computerfest and show in Trenton, attracting hundreds of vendors from the East Coast area. While the commercial vendors set up booths indoors with elaborate displays of equipment, the hobbyists set up shop in the parking lot. From the trunks of their cars, they sold everything from used, often obsolete, equipment, to the most minute parts of a computer's innards. People go there to look for parts to upgrade their equipment and to unload items they no longer use. One man described the fair as the kind of place where "nobody really makes any money because everybody just shifts a computer or two to the left."

The infiltration of American life by computer technology happened so rapidly (in little more than a decade) that the formal channels of education were unable to keep pace with the changes. In the same way that, earlier in the century, automobile owners formed groups to service their cars, computer user groups arose to fill the gap between the need for information and its availability. They are still a growing phenomenon, particularly because new groups spring up to help stranded owners whenever a computer company goes out of business. Although there are no precise membership figures, there are more than three thousand groups in the United States alone, with a total membership probably numbering in the hundreds of thousands. Individual groups range in size from a half dozen to thousands of members. The world's largest is the 15,000-member Toronto PET User Group (PET was the original name for Commodore).

Other than dues, there are no qualifications for membership in a user group. Consequently the groups are fluid, and if they are to survive, they must adapt to the needs of an ever changing and frequently very diverse membership. Even at NYACC, there is a range of expertise, and it sometimes leads to comical exchanges. One man cannot figure out why his computer isn't doing what it's supposed to. Someone suggests that he load the programs onto the hard disk, then "put a virgin disk in drive A." "I did that, and it didn't work." "I told you. Put in a virgin disk." "I did!" "Did you put in a virgin disk, an *unformatted* disk?" the adviser asks, by this time exasperated. "No, it wasn't unformatted." "Well, a virgin disk is an unformatted disk," the adviser explains, with a slight trace of humor in his voice. "Oh," the man responds, innocently taking the bait. "I didn't know what a virgin is." Everyone laughs.

User groups run the gamut from fairly elementary, hobby-oriented clubs connected to such mass-market machines as Commodore and Atari to sophisticated groups that focus on learning programming languages more advanced than BASIC (such as C, a versatile language that allows the program to run on a variety of computers and that closely controls computer hardware functions). Some of the groups have a businesslike concern with mastering specific programs for on-the-job use; others are just intrigued with exploring the possibilities generated by computers.

Members may remain in a group because they feel attached to a certain type of computer they have long owned, even though they have acquired another. (A member of the Kaypro user group refers to his two machines as "that IBM and my Kaypro.") Or, like craftsmen who appreciate old-fashioned, well-made tools, they may have a fondness for an old operating system, the underlying numerical code that activates the computer hardware. Bob Huber, who is trained as an engineer, markets IBM systems; he is also the chairman of a group that has a technical interest in an operating system known as CP/M. CP/M (Control Program/Microprocessors) was the first standard operating system for microcomputers. Huber is appalled by the amount of memory used by IBM's more advanced operating systems:

> You begin to feel that they have so much space available that they're not really writing tight, good programs. They got it. They use it. They waste it. CP/M people have to think differently: they have only 64K of memory; they can't squander it. And they do some really, really good stuff.

User groups have a certain sense of Us (the users) against Them (the manufacturers). Members have all experienced the frustration of unintelligible manuals, misinformation, and given the general uncertainty of the market, the nagging fear that their model or even the manufacturer may not survive the latest shakeout. Consequently they have learned to rely upon one another for information, advice, and if the machine is no longer manufactured, help in repairing broken machines and knowledge of where to secure parts. (Even where manufacturer's representatives are available, members of user groups are often more knowledgeable about the repair of their machines, particularly older models.) At one group's meeting, members with malfunctioning machines set up their portable units and discussed the problems they experienced, soliciting suggestions and reviewing the "documentation" that would guide them through the maze of circuits to the chip that probably was at fault. I asked one man how he felt about having to learn to repair his own computer. "I like it," he replied. "It gives me a greater sense of control over the machine

A computer buff's car license plate proclaims his identity as a hacker.

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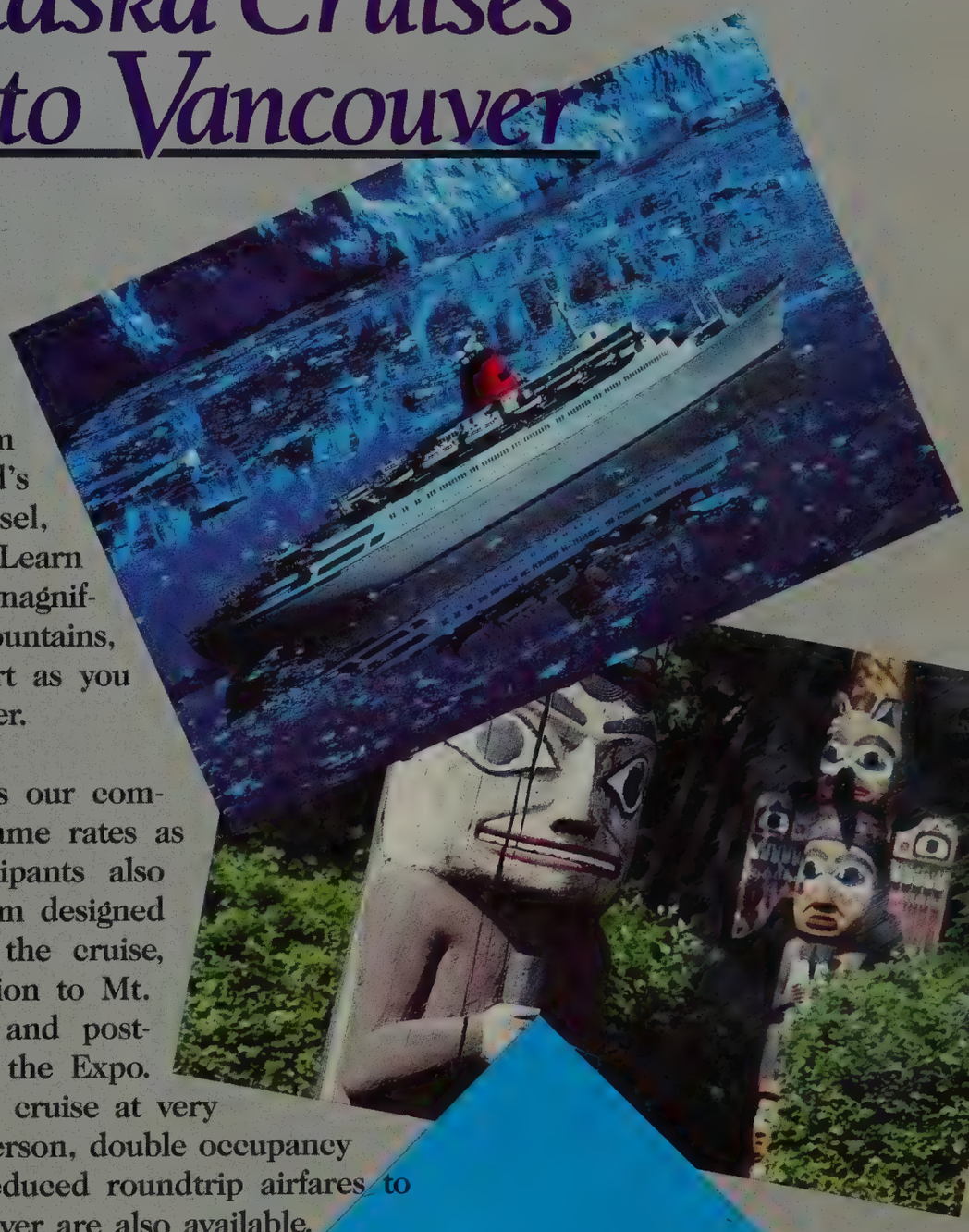

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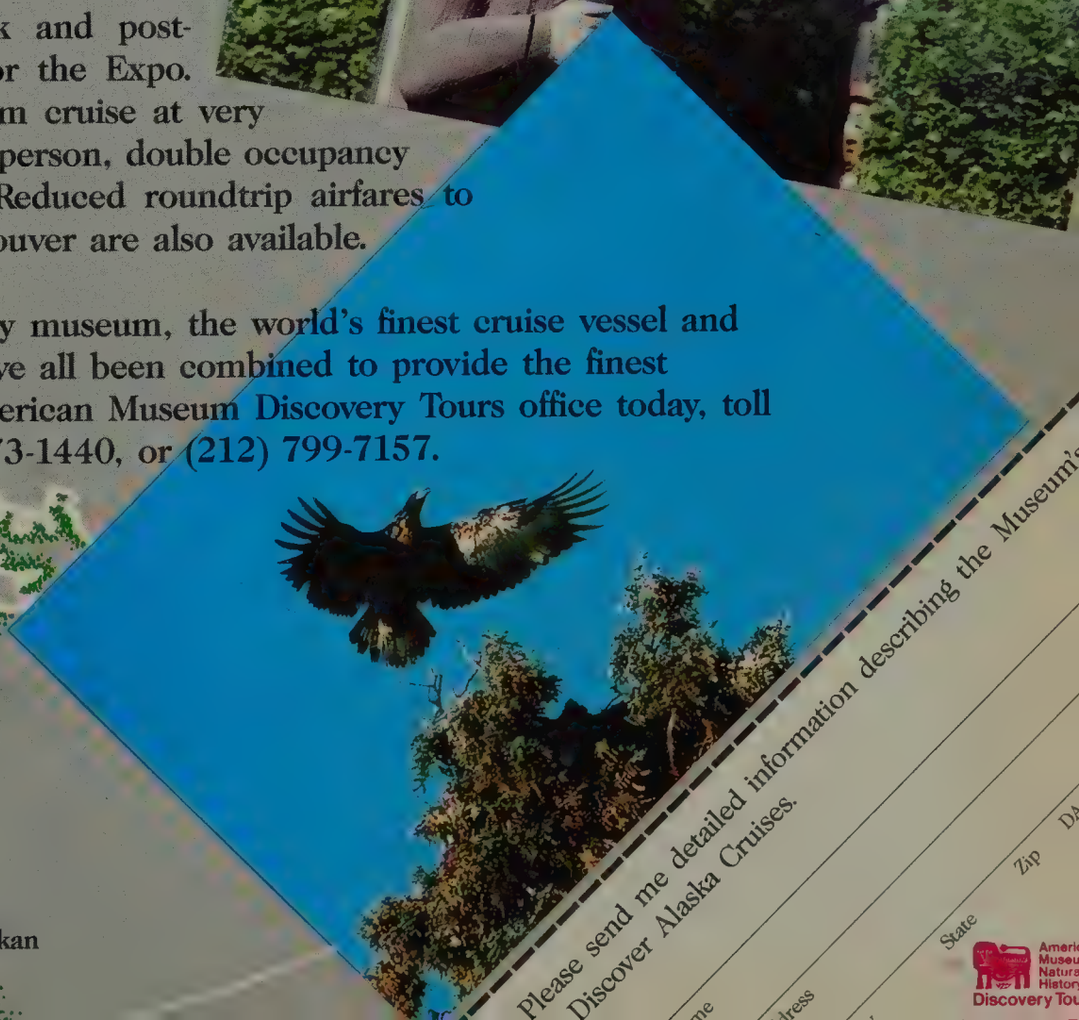

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I wouldn't have bothered with if I didn't have to, but I'm glad I can do it."

Similarly, user groups invariably engage at least their core members in the more esoteric aspects of computer software, even when they have no prior knowledge of the field or practical use for the information. Once they have begun to master the ever expanding range of computer technology, they are eager to learn more. Here the line dividing business needs and hobby becomes indistinct. Members look forward to meetings as a chance to talk some shop with similar-minded people and to go out for beer and a snack afterward. One of the side benefits of membership is the chance for people from diverse backgrounds to meet—businessmen with artists, programmers with writers and poets. The shared dilemma and the sense of Us versus Them help solidify these relationships into bonds of friendship.

Many of the people who attend user-group meetings know little about computers. If they share one thing in common with the more expert members of their groups—the ones who attend perhaps just for the challenge of the questions—it is being excited by the presence of something new and powerful in their lives that they are terribly eager to master. Gene Tulchin, an art professor turned computer addict, believes that this excitement lies at the heart of peoples' involvement with user groups, particularly as they begin to get the hang of the programs and see the connections between the things they've learned:

> Perhaps it's a little bit of eureka. I think the correct phrase is the shock of recognition. It's not what *it* can do or what *I* can get it to do, but "Look what can be done!"

Computer groups help people master not only the more esoteric aspects of computer use but also the most elementary tasks of how to turn on the machine and follow basic instructions. Much of it is handholding, and the time commitment can be considerable, particularly on the part of group officers. Joe King estimates that during his tenure as chairman he devoted some twenty hours a week to the Kaypro group. Some of the time expended is needed to arrange locations for meetings and line up speakers (who generally report on new equipment and programs), but a good part of the time is spent answering emergency calls from members. In one case a woman called after midnight, frantic because she could not print out her dissertation, due the following day. After making a quick diagnosis over the phone, King put her in touch with another member who was able to solve the problem. The dissertation went in on time:

Two kids mind their father's "store," the latest in small-scale enterprises.

> As I recall, she offered the chap an honorarium of some sort, and he informed her that she could either give him his regular fee, which would be $2,000, or shake his hand and thank him. She shook his hand. She also invited him to dinner.

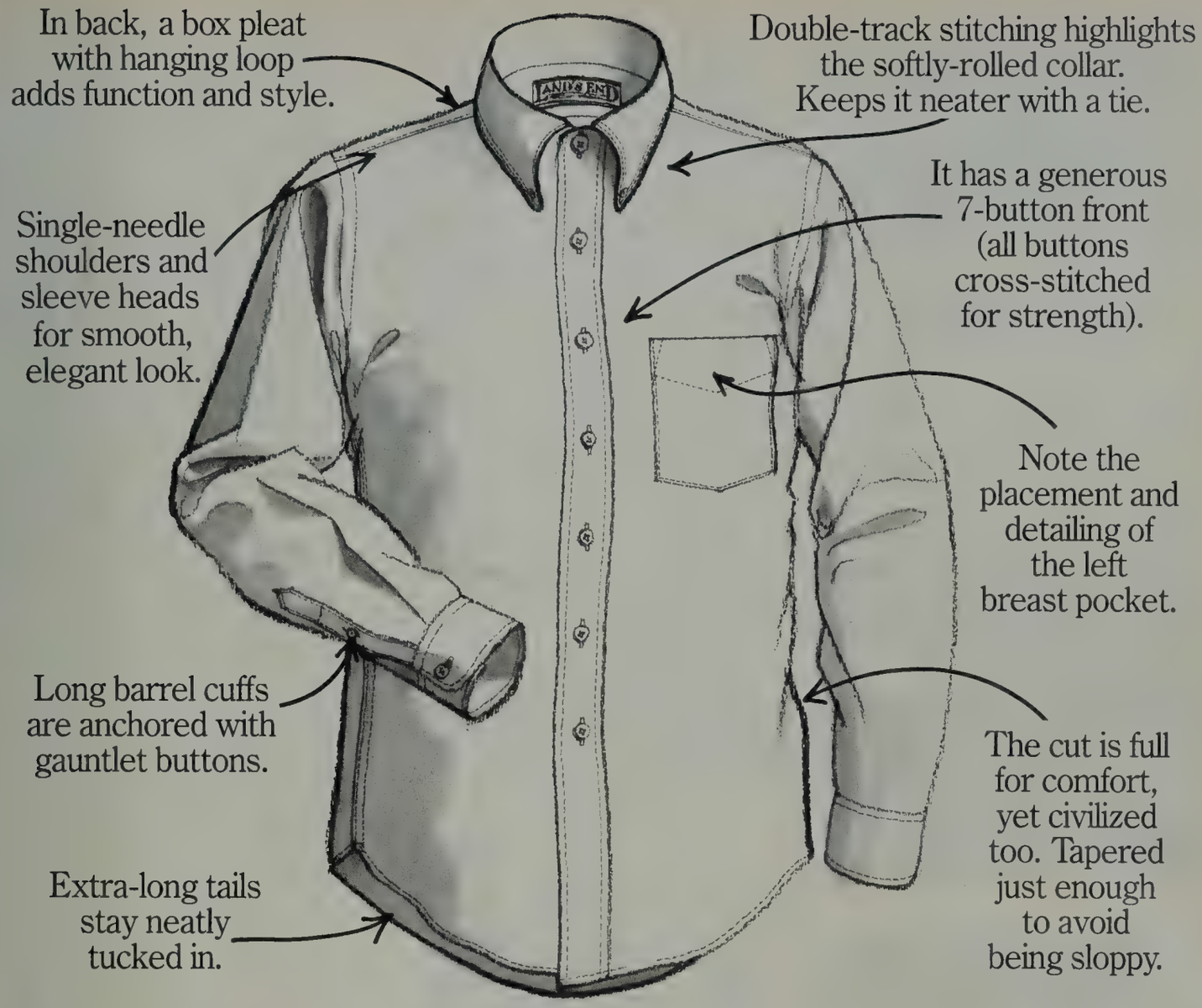
Although some manufacturers provide toll-free numbers in case of user difficulties, many problems spring up outside of normal business hours, requiring the help of a sympathetic and (since not everything can be explained over the phone) locally available expert. User groups give assistance at the meetings or by providing the home telephone numbers of group members. Jay Salzman, the current chairman of the Kaypro user group, has a low key, good-natured manner. His patience with first-time users stems as much from his own experience mastering the machine and its peripherals as it does from his personality. He spoke of how he learned to use a modem (the device allowing computers to communicate with one another using telephone lines) to contact the group's bulletin board, a computer-operated message exchange.

> A year ago, when the bulletin board was in its infancy and I was in my infancy with the modem, I was on the board and couldn't get going. And up on my screen like Christmas lights was, "Hold on now, good buddy. Let's get your ass in gear!" I'll never forget that. With that he proceeds to prompt me. I don't know who he is now. Lo and behold, I'm going so fast I'm confused, and I don't record the instructions. The next night I call and I say, "I'm embarrassed." He says, "It happens to all of us." And he walks me through it again. Only this time I knew I was getting it. I said, "Boy, you'd make a hell of a teacher! By the way, let me know what you do." And he says, "I'm a Catholic priest."

Like Salzman, King continues to contribute time to the Kaypro group, despite the occasional nuisance call. Just as some people helped him get started, he now feels that it's his obligation to help others, a repayment of sorts to the original source of information. King also believes in the so-called hacker's ethic, the principle—formulated by the maverick pioneers of computer programming—that the free flow of information is vital to the survival of society.

In their obsession with mastering the new technology, the early hackers regarded any system designed to exclude them as a challenge. They would break into supposedly secure computers and explore their programs, operations, and data banks, purely for the pleasure of unlocking their secrets. As Sherry Turkle wrote of hackers in her book *The Second Self,* these people have little interest in the applications of the machine. For them, "the means–ends relationship is dropped. The fascination is with the machine itself. Contact with the tool is its own reward."

The early hackers' demand that knowledge be shared emerged in support of this fascination. In his book *The Hackers,* Steven Levy notes that the hackers' ethic stipulated that "access to computers . . . should be unlimited and total" and that "all information should be free." Like other contemporary hackers, King lives by a less orthodox application of that principle: "Yes, it might be your profession to sell it. Fine. Sell it to your clients. Don't try to sell it to your friends or people who could become your friends." This commandment to share knowledge is central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■ MONEY BACK GUARANTEE ■

to the culture of user groups. Salzman summed up the attitude of most members of his group in the following way:

I don't really feel they're takers. I feel they're there to learn as opposed to take. In fact, in sifting through the membership data base, I was surprised to see under the "comments" column the number of people who used the words, "would like to help" or the phrase "can help someone with" or "will help."

Jeremy Shapiro is the organizer of the Northstar user group in New York. He is a sociologist in his mid-thirties who is currently pursuing a master's degree in computer science. Soon after he bought his machine he began attending NYACC meetings. At the time he was interested strictly in word processing: "I didn't know anything about computers. I didn't even know how to turn it on or what to do with it." There were a few Northstar owners who attended the meetings, one of whom lent him some software and custom built a cable that would interconnect his printer and computer. The two began meeting regularly with another Northstar owner and in time others joined the group. According to Shapiro,

I've been struck by the ethic of shared knowledge and information and mutual help that exists in the microcomputer culture in general. From the beginning that's one of the reasons I've put energy into the user groups. I don't know exactly what the basis of it is, but one thing is the belief in the value of gifts, even if it's just information—people going out of their way to look up articles that they read to give some people some information.

User groups are at odds, in a way, with the mores of the mainstream culture because they mandate a form of community among their members that, in Shapiro's words, "emphasizes sharing and the denial of private property." Perhaps the purpose of such sharing is similar to that of gift giving in nonmarket economies: the network of exchange defines the boundaries of the group, and the giving of gifts makes an individual a full-fledged member. As the essayist Lewis Hyde notes in his book *The Gift*, gift giving can be a means through which "a person comes into his or her social being." Here, a person's social being is membership in a kind of scientific community made necessary by the vastness of the intellectual undertaking. The gift, mainly the sharing of information, also contributes to the formation of "a group mind . . . capable of cognitive tasks beyond the power of any single person."

Perhaps the most concrete example of the free flow of information in computer user groups is the distribution of "public domain" software, consisting of both copyrighted and noncopyrighted programs donated by individual programmers. Originators usually specify that in public domain it is available only for noncommercial use and often reserve the option of making commercial use of the program themselves. Donations are made to any of several major public domain libraries and reach the librarians of local user groups through bulletin board systems. Librarians test the programs and prepare disks, each containing a number of public domain programs, which they sell at nominal fees to group members (revenues help cover a group's operating expenses).

The Kaypro user group software librarian in New York is Ken Thorpe, a forty-year-old computer wiz. He comes to the monthly meetings carrying a shopping bag containing copies of the latest disk the group is selling for an $8 charge. There are well over twenty other disks available, and Ken brings along a couple of copies of each so that new members can catch up. During the time allotted for commercial announcements, Ken usually gives a short summary of the contents of the disk he currently has for sale and the usefulness of the programs on it. One of the services Ken provides as librarian is backup information and help to group members who purchase a disk. This is in addition to the sixty hours he devotes to putting together the average disk, writing up the instructions and other documentation, and making the copies.

At one meeting, Tina Smith, an experienced programmer and one of the founders of the group, spoke at great length about an easy to use data-base (list-keeping) program she had written and made available on the group's current disk. She welcomed the opportunity to have direct contact with potential users of her work and hoped that the following month's meeting would provide the feedback she needed to continue "debugging" the program. Although Ken got a good deal of feedback in the form of questions about how to use the program, Tina got little response. The Kaypro group, she readily admitted, was writer, rather than "techie," oriented and was not the best forum for discussing a data-base program.

Sometimes, particularly within smaller, more informal groups, the free flow of information includes the unauthorized duplication of copyrighted software—a relatively easy thing to do with floppy disks and quite illegal. A member of one user group admitted that since he acquired his machine he has spent between $500 and $1,000 on software but probably

wns about $5,000 worth of programs. A ıember of another group stated that he as 400 programs but uses only 50. He xplains jokingly, "What we do isn't really .ealing, because we're just trying out the rograms."

Members of user groups are of two ıinds on the issue of pirating software. ome defend it in much the same way adicals of the sixties believed in "ripping ff" the system. Others are a little uneasy ver the ethics of pirating, particularly hen it hurts individual programmers as ell as corporations. One user-group ıember, who believes in equal access to ıformation on political grounds, has gone hrough several different phases of belief ın this issue. Currently he operates under he following rule of thumb: programs hat cost less than $150 he buys; those that ost more he pirates. He is critical of the xcessive profits of some software compaıies, but he is also aware that programıers (he has recently become one himelf) are entitled to fees for their work:

For example, I was using this program called Power—somebody had just given me his copy of it. And I went to this computer conference in California and met the guy who wrote it. I told him I was from this user group, and he said, "I'm really upset because I heard people in this group are copying this program." And you know he was an actual person. And I went back to New York and bought a legal copy of the program.

Groups grapple not only with the ethical dilemma of pirating but also with the nature and extent of the service they should provide for members. According to Gerald Gold, an anthropologist who is studying user groups in the Toronto area, there tends to be some tension in the larger and more successful groups between business-oriented members, who would like their group to expand and turn a profit by merchandizing its newsletter and related items, and the rank and file, who see the group as consumer or user oriented. The issue is difficult to resolve, particularly because the hacker's ethic persists as the underlying tenet of user groups.

Computer culture was invented by hackers, and it is carried on, much like a sacred tradition, by their successors. Although many today make their living as computer experts, the culture persists because it addresses and, to the extent that it can, modifies humanity's ambivalence toward its own creation—the machine. It does so by reasserting human control, bringing a formidable machine into the framework of human social exchange. At the same time, it justifies the fascination with technology by defining a loftier mission, the search for pure knowledge.

User groups champion the sharing of information, and in them, as one chairperson points out, "status is based only on specific knowledge rather than on presumed expertise." The groups transform novices into experts and then back again into novices as individuals begin to make their way through the intricacies of particular programs and attempt to communicate their knowledge to others. As Bob Huber put it,

One of the things that's hard to do with a computer is to be expert on anything. Things will happen, and you still won't know why the devil they're happening. They're immensely complex. You can think you know just about everything and come to a meeting and find out that you don't. And somebody who knows absolutely nothing can ask you the most inane question, and you realize all of a sudden you hadn't considered something like that.

Jack Kugelmass is on the faculty of the Max Weinrich Center for Advanced Jewish Studies at the YIVO Institute for Jewish Research, New York City. His book The Miracle of Intervale Avenue, *to be published this spring by Schocken Books, was written on a Kaypro.*

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White whales, waiting to ascend the river at high tide, gather in the crystal clear water near one of the arms of the Cunningham River delta, in Canada's high Arctic.

White Whales on Holiday

Thousands gather each year at favorite Arctic inlets, apparently for fun and chitchat

Text and photographs by Fred Bruemmer

As the tide rises, the white whales begin to swim up the channels of the Cunningham River's broad-fanned delta on the north coast of Somerset Island in Canada's high Arctic. As the whales surge through the cool, green, pellucid water, glittering bow waves curl against their bluff-browed heads, and their large, heart-shaped flukes rise and fall in smooth cadence. They jostle each other playfully and squeak and grunt. White whales are the most talkative of all whales. They have a repertoire of several hundred sounds, and because they often trill and whistle, sailors called them "sea canaries."

Slate gray immatures and glistening, brownish gray calves ascend the river with the adults. Neonates swim close to their massive white mothers, usually above her or near her side and aft of the dorsal ridge, profiting from the turbulence pull of the swimming adult or, as the Canadian scientist Keith Kay has put it, from "the hydrodynamic frictional coupling between mother and calf."

In their favorite river channel the whales pass close to a twenty-foot aluminum-pole tower, built on a gravel bar and topped by a small observation hut. As they come near the tower, the vanguard of the long throng of whales are a bit apprehensive. They turn upon their sides and glance at the tower with small, dark, sloe-shaped eyes. Unlike the fused and rigid neck vertebrae of most whales, those of the white whale are flexible. The whales turn their heads and look up at the scientists and technicians of Canada's Arctic Biological Station, who, in turn, look down at them. If one person makes an abrupt movement, the whales may panic. They groan and shrill, and the scientists' hydrophones pick up a frantic cacophony. The whales rush down the river, and even whales far in the inlet may respond to the alarm and dive. The whales can communicate over great distances. "The instant a white whale is shot or harpooned," noted the explorer-naturalist Peter Freuchen, "the rest of the herd disappears at once . . . [even] those far away in adjoining fiords . . . ."

At Cunningham Inlet no one bothers the whales. Their frantic fear soon yields to timid curiosity and they swim up the river again, rolling sensuously in the relatively warm, swift-flowing water. After nearly ten years of work by scientists of the Arctic Biological Station, the white whales are probably the most intensively studied whale group in the world.

Lancaster Sound, along with Barrow Strait, the eastern section of the famous Northwest Passage, is one of the richest sea-mammal regions of the entire Arctic. After battling Baffin Bay pack ice for weeks, the British explorer William Edward Parry was delighted when his ships, the *Hecla* and the *Griper,* entered Lancaster Sound in July of 1819. It was an arctic Eden. As polar bears ambled across the ice, the sailors tried to lasso them. On ice floes "sea-horses [walruses] . . . lie huddled together, like pigs, . . . and are stupidly tame." Giant bowhead whales lolled leisurely in the leads. On July 30, Parry saw eighty-two bowheads. Narwhals were "very numerous," and white whales "were swimming about the ship in great numbers . . . [with] a shrill, ringing sound not unlike musical glasses badly played." Parry had discovered the "headquarters of the whales."

Whalers responded immediately to this news. In the ensuing years, they killed the bowhead whales. When these became rare, they took any sea mammal that could be turned into oil and profit. The slow-swimming, easily panicked white whales were a favorite target. In 1883, the whalers killed 2,736 in Lancaster Sound and Baffin Bay. It was easy. Massed in favorite bays and inlets, the white whales were driven into shallow water, and Capt. William Adams reported that "when the tide recedes the white whales are left aground . . . and then the slaughter commences."In 1910, his crew killed more than 700 white whales in one inlet alone. The blubber from six to seven white whales yielded a ton of oil. The hide—good for belts and boot laces—was sold in Britain for one shilling and sixpence a pound.

When most of the whales were gone, the whalers went. Over the past seventy years, however, the whales have made a comeback. The bowhead, hunted to near extinction, is still rare in Lancaster Sound and Barrow Strait, but both narwhals and white whales now number more than 10,000 in this region.

The white whale, or beluga (a name derived from the Russian *byely,* or "white"), is a shallow-water, cold-adapted, circumpolar whale. Some 50,000 inhabit North America's arctic and subarctic seas, and an equal number live in the seas to the north and east of the Soviet Union. An Ice Age relict population of about 500 lives in the Saint Lawrence River. Adult belugas are swathed in fat, which serves as an energy reserve and protects them from the sapping chill of arctic water. The blubber layer on an adult whale can be six to eight inches thick and constitutes more than a third of its total weight.

Since belugas vary greatly in size and weight, their populations in various parts of the north are probably discrete. In the Soviet Union, the largest live in the Sea of

Okhotsk where males attain a length of twenty-one feet; the smallest are the White Sea belugas with males only thirteen feet long. In North America, the largest white whales, weighing nearly 4,000 pounds, are found along the Greenland coast. Baffin Island whales weigh 2,800 pounds, and the Hudson Bay whales, at a mere 1,300 pounds, are practically petite.

Belugas appear compulsively gregarious; pods vary in size from a few animals to more than 10,000 reported from the Soviet north. A few, though, are solitary and these single whales with wanderlust can end up in the oddest places. One white whale ascended Siberia's Amur River for more than 1,000 miles. Another was seen in the Yukon River 600 miles from the sea. A young white whale entered Scotland's Forth River in 1932 and was killed not far from the famous bridge that spans the Firth of Forth. Several have been seen in Alaska's Lake Iliamna; three appeared off Denmark's coast, one in 1964 and two in 1965; and in 1980 tourists on the small Balearic island of Formentera, in the Mediterranean, were startled to find an eighteen-foot beluga washed up on the beach. The most famous of all the straying whales, though, was a beluga that swam up the severely polluted Rhine in 1966. Promptly, but erroneously, dubbed Moby Dick (Melville's famous white whale was an albino sperm whale), it swam leisurely upriver past Düsseldorf, Cologne, and Bonn and became the sensation of Europe. Apparently oblivious to heavy river traffic and to the tens of thousands of whale watchers on shore and in small boats, the whale spent a month holidaying in the Rhine before returning to the sea.

Certain bays, inlets, and, especially, estuaries attract white whales, and they mass in their favorite spots each summer. When in 1789 the Canadian explorer Alexander Mackenzie reached the mouth of the river named after him, he recorded that "one of my men saw a great many animals in the water which he took first to be Pieces of Ice. . . . I immediately knew them to be whales." Today about 4,000 to 5,000 white whales spend their summers in the Mackenzie River delta region.

The whales migrate great distances, often in large numbers. In March they move northward along the west coast of Greenland, and "the herd," said Peter Freuchen, "may number many thousands of animals . . . ." On May 21, 1914, while crossing the Beaufort Sea ice by dog team, the explorer Vilhjalmur Stefansson saw the northward migration of white whales in leads of open water. During the next two or three weeks he saw thousands of them heading toward the Mackenzie delta. In 1960, a Russian scientist studying walruses near Wrangel Island off northeastern Siberia observed "a very large school of beluga . . . fifteen kilometers long . . . ." They were all migrating east toward the Bering Strait.

As soon as ice permits, the white whales take up summer residence in their favorit inlets and estuaries. About 4,000 assem ble in the mouth of the Nelson River 1,000 in the mouth of the Churchill River and 1,500 in the Seal River estuary, all o the southwest coast of Hudson Bay. Abou 4,000 belugas summer in Creswell Bay southern Somerset Island, and at high tid many ascend far up the Creswell River And 1,000 to 1,500 gather in Cunninghan Inlet, northern Somerset Island. Th whales arrive in the three- by five-mile in let about July 15, leave en masse two o three times during their sojourn (perhap to feed), and abandon the inlet altogethe about August 20.

The presence of so many whales in such confined areas intrigues scientists an

s the tide rises, whales begin to swim upstream, left. They may drawn by the river's relative warmth, and the sweet water may ease the hing of their molting skin. But they are wary in these narrows. If anything arms them, they turn and rush toward the broader waters of the inlet, below, hile sending alarm signals to whales throughout the area.

orries conservationists because the nassed whales are vulnerable to hunting hey were, until recently, hunted in the Churchill River) and to disturbance as industrial development of the north proceeds. (Some years ago, a consortium alled Polargas planned to build a giant atural gas pipeline from the high Arctic o the south that would have passed nrough Cunningham Inlet. In deference o the whales, the proposed routing was nifted eight miles west of the inlet. This roject is, at present, in abeyance.)

Scientists have advanced three reasons or these mass gatherings of white whales: ne estuaries are rich in food; they are a efuge from enemies; and they are relavely warm and safe nurseries for coldensitive newborn beluga calves. In recent ears, Thomas G. Smith of the Arctic Biogical Station, who now heads the longerm study of white whales at Cunningam Inlet, has proposed two more: the hales come into the inlets to molt and ney come to loaf and play.

Of all whales, the white whale is the east specialized feeder. It eats anything it an get, benthic or pelagic—from marine orms, bivalves, whelks, crustaceans, and sculpins, to flounders, salmon, char, and cod—consuming between sixty and one-hundred pounds a day. While the immensely numerous arctic cod are the whales' major food, more than one hundred prey species have been recorded. Yet whales killed in their favorite inlets and estuaries nearly always have empty stomachs, and Smith believes that their abrupt but brief (they usually return in a day or two) summer departures from Cunningham Inlet are feeding sorties.

Apart from humans, the white whale has only two enemies, the killer whale and, on rare occasions such as ice entrapment, the polar bear. "In the icy regions," wrote the nineteenth-century whaler-naturalist Charles M. Scammon, "the Orca (killer whale) delights in the pursuit and destruction of the White Whale . . . ." Fat and slow, with a top speed of nine miles per hour, the white whale cannot hope to elude a pack of swift, sleek killer whales capable of speeds up to thirty miles an hour. For the belugas, the shoal waters of estuaries are a haven from killer whales.

Most beluga specialists agree that the principal reason white whales congregate in estuaries is probably to make life easier for neonates. Belugas mate in late spring, and after a gestation period of fourteen and a half months, most calves are born in July and August, when the white whales are in the estuaries. While adults are sheathed in thick, insulative blubber, a newborn calf has only slightly more than an inch of protective fat. Immediately after birth, the calf is nudged to the surface to breathe by its mother or an "aunt" (a female remaining close to the mother during parturition), and thereafter it often rides upon its mother's back like a small space shuttle atop a bulky 747.

The protective mother uses her body to shield her calf from any danger and nurses it often by squirting extremely rich milk (containing about 35 percent butterfat) into its blunt, little snout. The Canadian white whale experts A. W. Mansfield, David Sergeant, and Thomas G. Smith believe that the "comparatively warm water of many rivers prevents the newborn calf from suffering from thermal shock or dangerous heat loss until it has put on a sufficiently thick blubber layer . . . " to withstand the sapping cold of the arctic seas.

Even in midsummer, the water temperature of the arctic seas hovers at a few degrees above freezing, but arctic estuary water can be surprisingly warm where meltwater from extensive plateaus trickles toward rivers across sun-warmed earth and rock. (The whales do not gather in the estuaries of icy, glacier-fed rivers.) The water temperature at the mouth of Cunningham River is 46 to 50° F., at the Seal River 53 to 60° F., and in the Mackenzie delta's Kugmallit Bay, where Inuit have hunted the massed white whales for at least six centuries, the surface water temperature reaches 64° F. in July.

The warm water is probably beneficial to the newborn calves, but it is not essential. I have seen females and neonates among ice floes in the Bering Strait and in the Chukchi Sea, and in Inglefield Bay of northwest Greenland, and Smith has observed them frequently among extensive ice fields in the Canadian north, where the water temperature is close to freezing. Nor is warm water the sole reason belugas gather in estuaries, since immatures, cows without calves, and fat old bulls are also

A neonate, below, rides atop its mother. A calf often plays or rests upon its mother's broad back and can cling with surprising tenacity to her rubber-smooth skin. When the whales are startled, right, they dive abruptly to escape danger.

part of the summer crowd, along with the gravid females.

Smith believes belugas also mass in shallow water to molt. The idea is not new. Ludwig Kumlien, a scientist with the 1877–78 Howgate Arctic Expedition to Baffin Island's Cumberland Sound, wrote: "One thing I noticed, when they [the belugas] go up the fiord they have a dirty appearance and color, and, according to some whalemen, are covered with parasites; but after they have been rolling and rubbing themselves on the sand-beaches for a few days, they look much smoother and their color is a creamy white."

In 1980, biologist K. H. Finley watched white whales ascend the Mucalic River in arctic Quebec's Ungava Bay. The turbid water hid their activities, but "it became apparent that several of them had been rolling on the bottom as their sides and backs were streaked with dark mud." Inuit beluga hunters told Finley that when the whales arrive at the Mucalic River they are "fat and yellow" but when they leave in the fall they are "sleek and white." One hunter, Nawkawalk, explained that "belugas go to the rivers for warmth. And like seals they molt their skins. They molt in the warm water. The whales acquire a new layer of skin. . . . I have seen this in the *muktuk* [whale skin] I have eaten."

At Cunningham Inlet, some adult belugas are the mellow yellow of ancient ivory, others are marble white. But whether these are the colors of before or after the molt is difficult to tell. The whales, often many hundred, come in from the inlet on the rising tide. Some scratch on the river bottom and one can hear in the hydrophones the click-clack of moving stones, but most whales prefer to rub and roll upon the tide-flooded gravel beaches. Splashing with powerful flukes, they drag one side across the bottom, then the other, repeat it on their backs, and finally, with a humping motion, undulate their bellies across the grit and gravel. Smith thinks the rubbing helps to slough off the old, yellowing epidermis.

The whales give every indication of enjoying their molt. They splash in the shallows for hours; occasionally, they keep it up too long. A safe sport on the rising tide, gravel scratching can be fatal on the ebb. The water recedes, a whale gets stuck, and

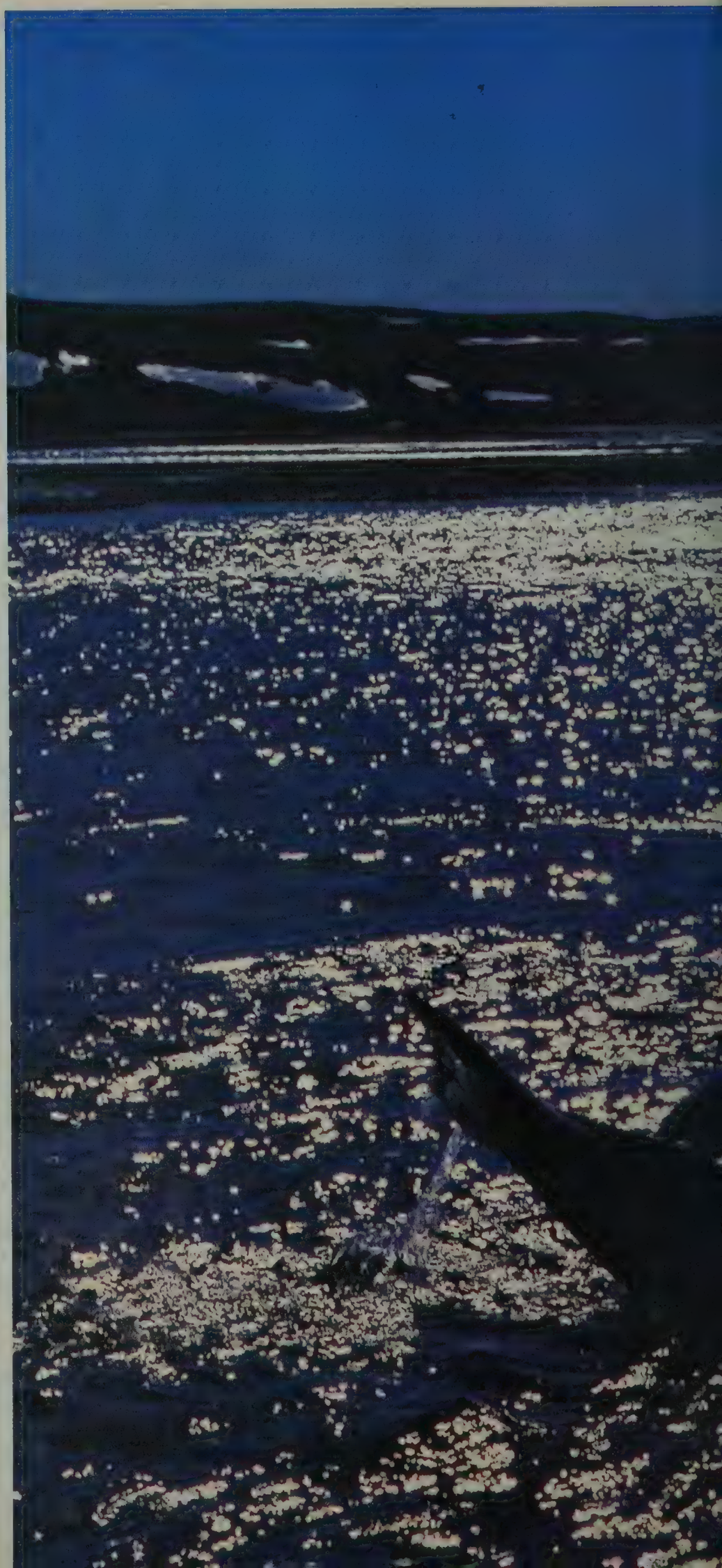
A white whale, left, rubs its belly on grit and gravel in shallow water near the coast, probably to ease itching or to hasten the summer molt by scraping off the old epidermis. The whales are curious and often "spy-hop," below, near shore to get a better view of their surroundings.

immediately becomes frantic with fear. It thrashes violently, cries loudly, and tries to hitch and hump its massive body into deeper water. Most whales usually succeed. But one bright arctic night some years ago, three whales—an adult and two immatures—swam at high tide across a submerged gravel bar onto a flooded plain. They returned too late, and on the ebb the gravel ridge barred their way. The whales splashed frantically but in vain. As the trapped whales screamed and groaned and trilled, the free whales, massed nearby in a deep river channel, answered in a chorus. I waded out into the river. Normally this would have spooked the whales instantly. But this time they ignored me. They surged back and forth a few yards from me, apparently desperately concerned about their stranded comrades. We kept the trapped whales wet to save their sensitive skins and eyes. When high tide refloated them, they joined the excited herd in the deep water beyond the gravel ridge.

At Cunningham Inlet the white whales play frequently and most seem to "talk" incessantly. The range of sounds that they produce is astounding. Various scientists have likened beluga sounds to bird calls, the bellow of a bull, the gritting of teeth, the grunting of pigs, the putt-putt of motor boats, the shrill scream of a woman, a squeaky snore, and the lowing of cattle. To this already impressive list, Canadian biologist Keith Hay, who did the first study of the Cunningham Inlet whales in 1974, added the following comparisons: a rusty hinge, a bell sound, a horse's whinny, a baby's cry, and a lecher's whistle. The whales, said Hay, also burp, chirp, croak, squeak, grunt, moo, mew, scream, and yap. In addition to all this brouhaha, the whales also produce clicks and pings, apparently for echolocation.

According to the Russian beluga expert S. E. Kleinenberg, the whales' "supracranial air sinuses [or air sacs] are the source of sounds, and the passage of air in them enables them to produce a wide variety of sounds of different frequency and intensity. The valve of the blowhole itself and parts of the pharynx also participate in the production of sounds. . . . The melon [a fatty bulge, with high sound conductivity, on the beluga's forehead] makes concentration and focusing of the beam of sound possible."

Three whales, caught in shallow water as the tide ebbed, were saved by the staff of Canada's Arctic Biological Station, who doused the animals' sensitive skin and eyes with buckets of water until the high tide returned.



The active whales vocalize more. They appear to be very curious. If you stand on the beach at Cunningham Inlet, they often swim past with raised heads or, treading water energetically with their broad flukes, push themselves halfway out of the water for a better look. (In aquariums white whales can recognize a familiar person among a crowd of strangers.)

The whales like to play with stones and seaweed. A male beluga dives and emerges with a long frond of seaweed swirling about its head. Other whales instantly rush at him, and there is a great deal of bumping and squeaking as they tear his trophy into tatters. A whale may swim around for hours with a plate-sized stone held firmly in its mouth. And often a whale will surface with a stone balanced skillfully but precariously atop its head. This rarely lasts long. The moment other whales spot the stone carrier, they bump and jostle him until the stone falls off.

This play with stones, Smith thinks, is the amusement and pastime of very intelligent animals. Another "game," though, may have a tragic origin. We have occasionally seen whales carrying planks or pieces of driftwood on their backs or heads. Smith believes these are females that have recently lost their calves. When a calf dies, the mother tries to support its body at the surface in the life-giving air, sometimes for many days. When she finally loses the calf, she may adopt a chunk of wood as a surrogate baby.

Early in August the first whales leave Cunningham Inlet. Noticeably fewer ascend the cooling river. The molt is presumably completed, the calves' fat layer may have doubled since birth, and food beckons elsewhere. By mid-August only a few stragglers remain and they are gone by about August 20. The white whales at other arctic summer resorts leave at roughly the same time. They spend the winter in polynyas, extensive areas of open water in the Arctic. Next July the white whales will return to the swift-flowing water of the Cunningham River, to molt, to play, to bear their young—and to "talk" loudly and endlessly, but despite the best efforts of Smith and his colleagues, no one as yet knows about what. □

A Matter of Gravity

Photographs by Peggy and Erwin Bauer

The Ponchatoula heronry near Louisiana's gulf coast harbors a handful of cattle egrets and dozens of pairs of adult little blue herons and their young. The four-acre swamp pond offers prime breeding habitat, and by late spring each year, the activity borders on chaos. Just after dawn, the heronry begins to buzz with incoming and outgoing flights of little blues tending offspring in various stages of development. The downy hatchlings are nestbound, but lanky white youngsters a few weeks old venture from the flimsy nest of twigs onto tree limbs to practice hopping and flapping. (Little blues don't acquire the species' characteristic slaty plumage for two years.) Coated with algae and ringed with softwoods, the Ponchatoula swamp provides favored nesting sites in trees overhanging the water, as well as the preferred shallow, freshwater feeding grounds. Adult little blues wade in ponds, marshes, and flooded grasslands, stalking fish, frogs, crustaceans, and insects. After consuming the prey, they return to the heronry and bring up the partly digested food for the two to five ravenous chicks in each nest.

The heronry is a raucous place of screeching, greedy, vying siblings. "The actual act of feeding," wrote a judgmental Dr. Cordier in 1923, "is . . . a vicious and terrible affair." Both parents feed young; chicks stimulate the adult to regurgitate by grasping the parent's bill and wrenching it downward with, Cordier noted, "bulldog tenacity." Access to the bill means survival to a chick. Weak and timid birds simply starve. If no stiff wind wrecks the nest and no crow or raccoon raids the tree, runt may be dispatched by a brother's well-aimed wing jab. Even when all the obvious perils are checked, life in a heronry remains precarious.

Early last June, photographers Erwin and Peggy Bauer

headed for the Ponchatoula heronry. For several days, they monitored some fifty pairs of little blues and their chicks from a blind of vines and honeysuckle about fifty feet from the action. They had focused on a nestling's bid for food when a small drama began. A lunge for the parent's bill set the gangly young heron off balance. As the chick screamed and struggled, the parent offered no more than a moment's startled glance at its contortions. For a full five minutes, the chick struggled to right itself, finally managing to hook its neck over the limb and win back its perch. But young herons are abundant and predators are patient. Another swamp dweller eyed the birds and waited. When the next chick fell, the Bauers were alerted only by a swirl and a slight lapping sound as the alligator surfaced and moved in on its prey. The end was a matter of just one gulp and a token that nature, in the end, is always efficient.—*Judy Rice*

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For hundreds of years, yak caravans have been the essential vehicle of Tibetan trade. Although some of the animals in present-day use have been crossbred with other bovines, many are descendants of the original pure-blooded wild yak and have retained that indigenous animal's physiological adaptations to the oxygen-poor atmosphere of the Tibetan plateau.

Thomas Kelly

Tibet's All-Purpose Beast of Burden

On the oxygen-poor Tibetan plateau, yaks—and their nomadic owners—have adapted physiologically to a high-altitude life-style

by James W. Larrick and Kathy B. Burck

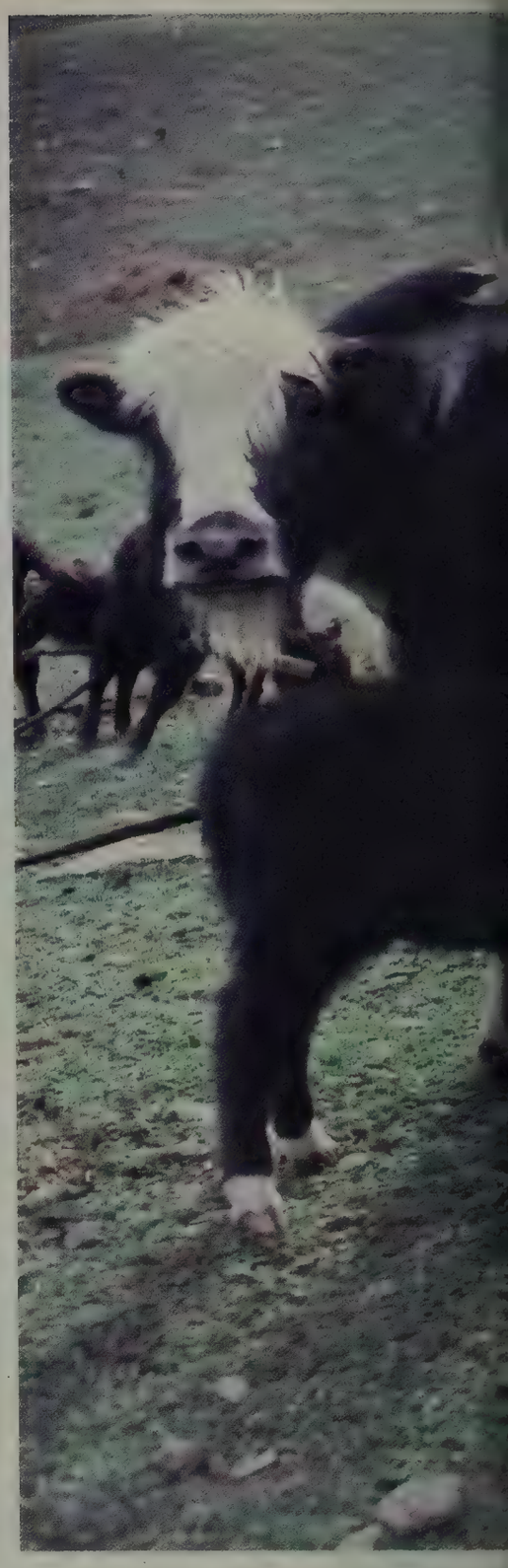
Yeshi Lhamo, a 68-year-old Tibetan, gestured animatedly as she described her nomadic life as a yak milkmaid. "When I was a girl, men from our village would travel four to five months across Tibet in long yak trains to get salt at Ch'iang-t'ang. Forty or fifty animals for each man!" In Yeshi's youth, Tibetan nomads conducted a thriving trade—bringing the salt south across the high Himalayan passes into Nepal and India, where they would then exchange it for grain and other goods. Yaks played a central role in these efforts. Although the trans-Himalayan commerce diminished after the Chinese occupied Tibet in 1959, nomads and their animals still ply the steep trails and mountain passes of the area.

We had seen many yak caravans along Nepalese trails in remote regions near the Tibetan frontier, where we were setting up medical clinics and studying the physiology of the people who lived at these high altitudes. There we began to learn firsthand about these animals and the people whose lives revolved around them.

Our interest in how living organisms adapt themselves to extremely high altitudes was one of the factors that had brought us to this corner of the world on expeditions in 1972, 1977, 1980, and 1985. Sometimes called "the roof of the world," the Tibetan plateau stretches across central Asia, north of the towering Himalayas, 12,000 to 20,000 feet above sea level. No trees or shrubs grow at these heights, and agriculture is difficult; animal husbandry thus constitutes an essential part of the livelihood of those who inhabit this region.

Herds of wild yaks (*Bos grunniens*) once roamed the Tibetan plateau, but so many were killed or captured for domestication that they have been brought to the edge of extinction. Today fewer than 500 remain in the remote pastures above 16,000 feet. Distinguished from their domesticated relatives by heavier builds, larger and longer horns, and more stubborn and nasty personalities, yaks were until recently hunted for food. Yeshi had never seen a wild yak near her village, but she had eaten their meat: "Eight or nine of our [domesticated] yaks were necessary to

Richard Gordon/Wheeler Pictures



On their journeys, Tibetan nomads pitch their tents wherever they may be while it is still daylight and herd their animals close to their tents for the night. Women milk the female yaks, called naks, several times a day.

Kevin Kling

carry down meat from a single one of them," she recounted.

Domesticated pureblood yaks are currently raised in the Himalayan highlands regions of Ladakh, Sikkim, Nepal, and Mongolia, as well as in Tibet. But pureblooded yaks are not the only bovine species found in these regions; crossbreeds with humped Zebu cattle (*Bos indicus*) and hill (Tibetan) cattle (*Bosaunus typicus*) are also common. Not surprisingly, given the central role these domesticated animals play in the lives of the nomads, there are many words both in Tibetan and Nepali for each breed, gender, and individual. The word *yak*, for example, refers only to the pure-blooded male *Bos grunniens*. *Nak* means female yak in Nepali; *dri* or *dree* is the Tibetan word. In Nepali, the generic term for any crossbred animal is *dzo*, but each offspring, grandoffspring, and great-grandoffspring (male or female) has a kind of surname that depends on parentage. In addition, each animal has a given name based on its physical characteristics. Two of Yeshi's favorite animals were called *Gyangsetama*, or "colorful one from a distance," and *Shego-gama*, "clear, white, and round as a mirror." Most purebred yaks are black with a few flecks of white sprinkled over their coats. A pure white yak is a rarity. In sixty years of raising yaks, Yeshi had only owned one.

In Yeshi's home village of Damshung, there are about two hundred families; each keeps at least one hundred yaks and sometimes several hundred. Here, most of the animals are killed for meat at the age of ten to eleven years, although occasionally a favorite animal is spared and allowed to live the normal yak life span of twenty to twenty-five years. Yaks mature in five to seven years, a longer period than that of lowland cattle but consistent with human populations that live at high altitudes, where a slower growth rate, prolonged adolescence, lack of adolescent growth spurt, and delayed sexual maturation is typical. In Damshung, and elsewhere on the Tibetan plateau, naks are usually mated in autumn so that they will calve nine months later in the milder weather of April or May when the chances of calf survival are greatest. Naks used for milk production are bred every other year. Curiously, and for unknown reasons, crossbred yak cattle have a longer gestation period—ten months—than purebloods. Crossbreeding also has its effect on fertility: although first-generation female crossbreeds are fertile, their brothers, because of a defect in the production of sperm cells, are not.

Yeshi told us that the best times of her youth were when she accompanied the yak herds over the mountain passes, visiting pristine lakes and flower-filled highland pastures. For one or two months during the short summer, the nomads brought their yak herds far from their home villages to higher grasslands. At those high altitudes, the atmosphere contains only about half the oxygen of sea-level air, and the nights, even in summer, can be bitterly cold.

To survive in that hostile environment, yaks have evolved some highly specialized strategies over the millennia. Domesticated purebloods retain certain of their wild relatives' traits: exceptionally heavy

coats and very few sweat glands, a combination of heat-conserving characteristics that makes it next to impossible for them to survive in lower, warmer climates. Probably more important are the physiological idiosyncrasies of the yak bloodstream. The red blood cells of *Bos grunniens* are only about half the size of those in sea-level bovines, and there are three to four times as many of them per unit of blood volume. Surprisingly, however, yak blood contains a comparatively small amount of the oxygen-carrying protein, hemoglobin—a mere 12 grams per 100 milliliters, even less than the 16 grams of human beings living at sea level. The paucity of hemoglobin is puzzling. European mountain climbers and South American Indians of the Andean high plateau have proportionately more hemoglobin in their blood than people who live at lower elevations, and the increase seems to be roughly linear with increasing altitude. If hemoglobin is the key to increased oxygen-carrying capacity, why don't yaks—living where atmospheric oxygen is in such short supply—have an especially high volume of the protein?

The larger number of smaller-sized red blood cells may be part of an alternative mechanism for obtaining oxygen. Theoretically, small red cells with their high surface-to-volume ratio, can pick up more oxygen molecules than larger red cells, thus partly offsetting the need for extra hemoglobin. It is also possible that yaks have a type of hemoglobin analogous to that in the human fetus. Human fetal hemoglobin, with its greater affinity for oxygen, is able to pick up sufficient amounts of the element from the low concentrations in fetal blood. Blood tests we made in our clinical work on Tibetans and others of Tibetan stock, such as the Sherpas and Tamangs of Nepal, indicate that their blood appears to have a greater affinity for oxygen than does the blood of other people. Chronic mountain sickness (a disease that afflicts Andean natives, as well as lowlanders when they climb to high altitudes) is unknown among Sherpas and

Tibetans. Their resistance could be related to blood adaptations.

Whatever physiological similarities may or may not exist between yaks and Tibetan nomads, there is no doubt that the animals are of utmost importance to the economy and life style of these high-altitude people. Yak skins provide both clothing and shelter. Yak hair is of two varieties: long, coarse outer hair and fine, underbelly inner hair. Blankets, rope, bags, mats, slingshots, halters, and tents are made from the outer hair. In his book *Seven Years in Tibet*, Austrian mountaineer-adventurer Heinrich Harrer relates how well-suited the nomads' yak hair tents were to the windy cold of winter on the Tibetan plateau. (Yeshi told us she lived some of her life in such a tent but usually resided in a more permanent stone house in Damshung.) The fine inner hair of the yak is used for blankets and for clothing. "Only hair from young yaks two or three years old can be used for clothing. The hair from older animals is too coarse," Yeshi told us.

Yak hides are used to make oblong-shaped boats known as coracles, which are nine to twelve feet long and six feet wide. They are constructed by stretching raw, uncured yak skin over a framework of birch or willow branches obtained from trees that grow at lower altitudes. These boats are used for downstream transportation on some of the larger waterways. They are too unwieldy to be rowed or towed upstream but are light enough for one man to carry on his back when he returns upstream to his starting point.

Hides are also made into belts, carrying sacks, and saddlebags and are used for the soles of traditional Tibetan boots (the boot tops are usually woven). For these purposes, the hides are cured so they can be worked more easily. According to Yeshi, "To cure hides, we treat [them] with salt and then with butter. This makes the skin soft so we can use it."

Yak meat is a staple on the Tibetan plateau, where agriculture is almost nonexistent. Tibetans are Buddhists and therefore not supposed to kill animals for food. To get around this difficulty, people in major cities such as Lhasa used to recruit members of the lowest class of Tibetan society—a stratum akin to the Indian Untouchables—as butchers. In the nomads' home villages, however, people slaughtered their cattle themselves. Females were usually slaughtered at sixteen to twenty years, five or six years later than males, and only after they had lived out their milk-and calf-producing life span.

Tibetans are also not averse to eating animals that have died accidentally or have been killed by such wild beasts as snow leopards or wolves.

Any meat obtained in winter is eaten fresh or put in "cold storage"—hung up under the roofs of houses. In summer, meat is cut into strips and smoked over a fire. The highland people trade some of their meat, as well as live animals, to lowlanders for grain, especially barley, used in making the Tibetan staple food of *tsampa*, a paste of roasted barley flour and butter that is rolled into balls and eaten with the fingers.

Occasionally, Tibetans bleed their yaks, ostensibly for the animals' health. The blood, however, is sometimes mixed with salt and a bit of water and left to solidify. It is then cut into pieces, fried or boiled, and eaten. Alternatively, the blood

Kevin King

Agriculture is impossible on the high plateau, but at lower altitudes, Tibetans grow barley and other grains, using their yaks to pull their plows. Yak dung, below, is gathered, patted flat, left to dry out, and used later as fuel, primarily for cooking.

Kevin King

may be mixed with *tsampa* and baked into a form of bread.

When she worked as a milkmaid, Yeshi milked her naks two or three times daily in order to prepare butter and curd, a form of yogurt. Damshung, she said, was "known all over central Tibet for the quality of its butter." As in days past, butter is still made in churns (*dongmo*) the size of twenty-five-gallon drums: "I fill the *dongmo* with yak milk and give it 200 strokes . . . the butter floats to the top and I take it out and store it inside a yak stomach wrapped in yak skin," Yeshi recounted. Her butter fetches a premium price—currently twelve yuan for 2.2 pounds, about $1.50 per pound. Curd is prepared early in the morning "from yak milk brought just to boiling" to which old curd is added. "By evening we would have delicious curd."

Nak milk and its products—butter, cheese, and curd—are also staple foods. Milk is generally not consumed fresh, especially not by adults, but curd and buttermilk are relished. Solidified buttermilk makes a dry cheese called *sherkam*. Milk slowly dehydrated by boiling until it assumes the consistency of toffee is known as *korani* (in Sherpa). Most of the milk goes into the production of butter, a product needed both for daily living and for religious affairs. Butter is used for cooking, as an ingredient of *tsampa*, and is spread on flat Tibetan bread. Another use is the famous Tibetan butter tea. "The black tea comes in bricks, from China," Yeshi told us. "We break off part and boil it, then we mix it with butter and salt in the *dongmo*." After churning in the *dongmo*, the butter–tea mixture is quite homogenized.

Tibetans always offer their guests hot tea and Yeshi sipped hers with relish as she talked with us. We found the tea barely palatable, tasting something like warm seawater. Tibetans are known to drink twenty to forty cups per day of their salty butter brew. This large consumption of salt may partly explain the prevalence of high blood pressure we found in the inhabitants of several Tibetan villages.

Yak butter is also burned in small lamps lighted in the course of Buddhist ceremonies. Heinrich Harrer described rooms in monasteries where hundreds of these lamps were flickering around the gilded idols. Most families have their own home altar where several butter lamps burn continuously. In addition, the butter is a major ingredient in huge sculptures, sometimes two or three stories high, fashioned by monks for religious ceremonies such as the New Year celebration. The

:mas Kelly

fully loaded yak can carry up to 120 pounds even on a steep pathway. ak horns inscribed with prayers, below, are installed in monasteries Nepal as protection against evil spirits.

Wolfe

ulptures are kept in the shade to prevent elting and are later burned as offerings the gods. Because of heavy religious nsumption, a large amount of yak but- r is produced.

Butter, a valuable trade commodity for e nomads, is sometimes used to pay ages to those who work in the fields or lp to build village houses. It is also used hair grease and for curing yak hides to make leather. Because of the cold Tibetan climate, butter is often stored for a number of months in the yak stomach containers described by Yeshi. However, the two-week-old butter we sampled would surely be considered rancid by Western standards.

Yak horns were sometimes made into utensils. In the Khumbu region of northeastern Nepal, the Sherpas place yak horns in their monasteries to protect them from a Dracula-like spirit, called *Bhut* in Nepali. Tibetans inscribe mantras on yak skulls and hang them up in their homes.

Yak tails are most frequently used for rope making, but they are used for religious purposes as well. Tail hair also decorates the prayer cylinders erected on the roofs of monasteries. Because of its rarity, the most highly valued hair used for this purpose is the white tail called *gnuri shanker* in Nepali. Interestingly, yak tails were often exported. Before the advent of synthetics, for example, the beards of department store Santa Clauses in the United States were made of black yak tail hair bleached white.

Even yak dung is precious. It is an important source of fuel, especially for Tibetans living above the tree line. In the past, soot from burned dung was collected and made into ink that monks used in their monestaries.

In years past, yak caravans made trade possible throughout the rugged Himalayan region. Today yaks and crossbred cattle make shorter hauls. They can be seen slowly climbing and traversing the steep and narrow trails between villages and settlements. We often watched the caravans plodding along in trains as small as two or three animals and as large as twenty or twenty-five. Although they were easy to outdistance at a normal human walking pace, fully loaded yak trains often covered ten to fifteen miles in a day. A typical animal weighing only 600 to 800 pounds might carry a load of 100 to 120 pounds. We rarely observed riders on yaks; drivers generally followed on foot, poking the rear animal with a stick so it would keep those ahead of it moving.

Yaks' noses are often pierced, and a brass, wood, or leather ring is inserted to aid in controlling the animals. As evening approaches, yak trains stop at caravansaries and the animals are unloaded and allowed to graze until morning. Some of the large trains include several unloaded animals that are rotated with loaded ones on a day-to-day basis. In the agricultural regions at lower elevation, where barley and other grains are grown, yak teams pull the heavy wooden plows. According to

anthropologist Christoph Von Furer-Haimendorf, until the 1930s, the plows were pulled by men.

More than twenty-five years have elapsed since the Chinese occupied Tibet and the Dalai Lama, the spiritual leader of the Tibetan people, fled to India. The invasion of their homeland brought considerable hardships to the Tibetan nomads. "The years after 1959 were bad times," Yeshi remembered. "People were taken away, all our yaks were confiscated, and many individuals, including my husband, Norzang, fled." Much of the trans-Himalayan trade diminished and with it the number of yaks. In the 1960s, Nepal had an estimated 200,000 yaks. By the 1980s, the number had dwindled to fewer than 20,000.

Yeshi still spends part of the year in Damshung where she, her parents, her grandparents, and her children were born and raised. She lives with her oldest son, the second of five children, and has ten grandchildren, most of whom also live in Damshung. Have things changed since the bad times following the Chinese occupation? we asked. "Now things are better than they were," she answered. "The Chinese gave back our yaks about six years ago and two years later they let a Tibetan lead the village commune. But we still have to pay yearly taxes in the form of milk, wool, and meat." Tibetans currently give twenty *gyma* (about twenty-two pounds) of butter for each nak they own, and for every 100 animals in their herds, one yak is killed and given to the Chinese for meat. Although the Chinese sharply curtailed the Tibetans' nomadic life style when they organized communes in the villages, things may be changing. Yak caravans have recently been reorganized for limited trade within Tibet. Trading activity across the Nepal–Tibet border is still restricted, although both governments may soon relax their security and permit the revival of trans-Himalayan trade.

We asked Yeshi what she would most wish for the future. "I am old," she said, "but for my children and their children, I would want them to have the freedom to cross the mountains in yak caravans and to see the beauty of our land." □

Hemmed in by mountains to the north and the south, Tibet has been largely cut off from the rest of the world. Following the Chinese takeover in the 1950s, active trade across the Himalayans was restricted. But limited trade has since been revived within Tibet,and yak caravans are again plying their way through the mountains.

Thomas Kelly

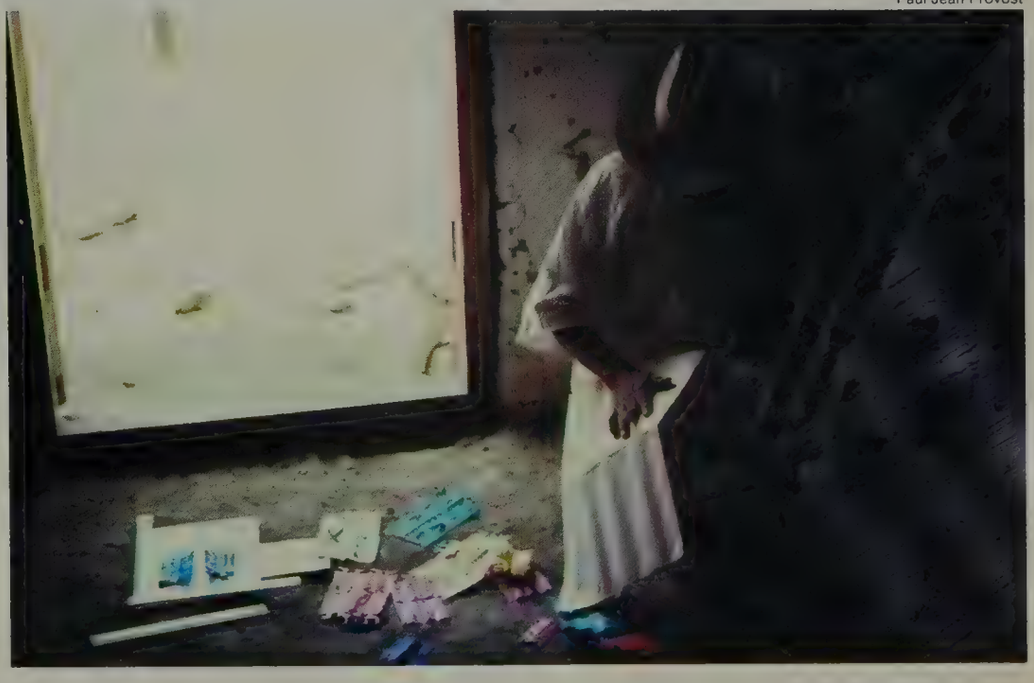
oqmí Indians in San Pablito cut paper ages of spirits, left, from locally made rk paper and colorful commercial pers. A Nahua Indian shaman, or rer, below, cuts images of disease- using spirits for a cleansing ritual.
id Hiser

Paper Spirits of Mexico

laborate rituals, long hidden in remote Indian villages, provide a glimpse of Aztec cosmology

y Alan R. Sandstrom

Paul Jean Provost



"If you want to see something, Alán, me to my compound this evening." ith Antonio's simple invitation, I had y first opportunity to witness a ritual oted in the ancient religious practices of lesoamerican civilization.

Five months earlier I had arrived in a ahua Indian village in the Mexican state Veracruz to study the relationship be- veen horticultural practices and religious tuals. I selected a village in the township Ixhuatlán de Madero, in a remote re- on of the Sierra Madre Oriental, in the pe that ancient rituals survived there. ans Lenz, an explorer, reported in the 940s that traditional rituals abounded in e area. He noted that shamans, or cur- s, cut paper into silhouette likenesses of irits for use in curing and fertility ritu- s. Historians have long known that the ztecs cut paper for their rituals, and the ssibility that the practice continued mong their Nahua descendants was in- iguing to me.

The villagers I interviewed were more an willing to talk at length about their ltivation techniques, but they were less rthcoming about religious matters. Ask the shamans, they know about such ings" was the typical response, yet the ur practicing shamans in the village as- rted they did not know about such ings either. I proceeded with caution, eeping in mind what Lenz had written in 948: "It is dangerous to penetrate the ierra de Ixhuatlán beyond a certain oint. This is particularly true if the object f the trip is to gather information on the agano-Christian customs of the Indians ho live there or to collect samples of apers they cut for their offerings and itchcraft."

Then one day, when I was visiting my riend Antonio's compound, I noticed a lothesline strung through the open area between buildings. Hanging from the line were some seventy-five tiny cloth outfits, miniature versions of the clothing worn by Indians in the village. When I asked him about the clothes, Antonio extended the invitation.

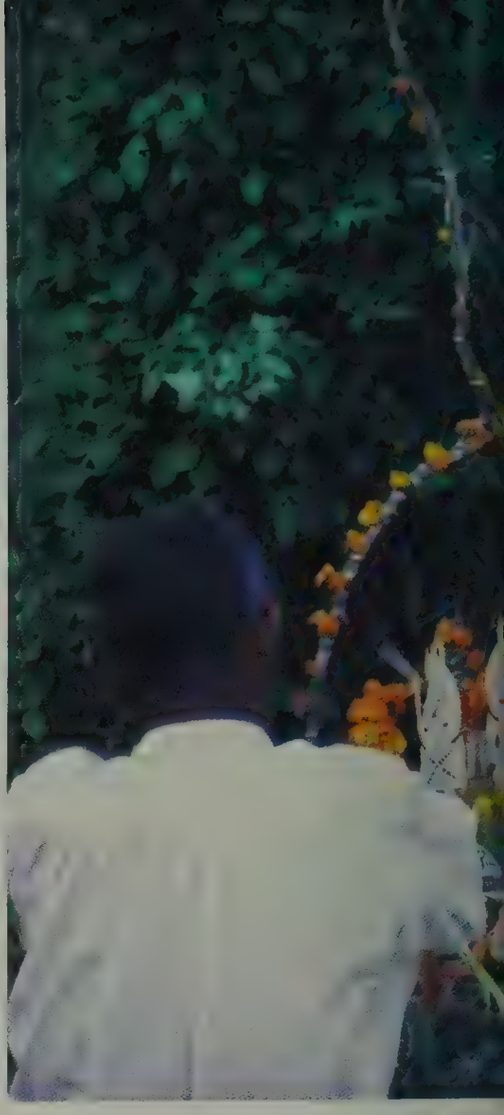
That night, as I approached Antonio's compound along a path through the tropical forest, I could hear the slow, repetitive violin and guitar melodies that accompany all important Nahua rituals. When I entered the thatched dwelling, fifty people turned and stared at me through thick copal incense smoke. Antonio rose to greet me and, one by one, each person approached to touch their fingertips to mine, softly intoning *piali,* the traditional Nahua welcome.

Greetings completed, Antonio (who I later learned was an apprentice of the most powerful shaman in the village) explained that the community ritual they were undertaking was held each year before the spring planting. It petitioned the spirits for rain and insured fertility of the fields. He told me that thunder and lightning spirits carry rain inland from the sea to caves at the summits of twelve sacred hills, where it is released by *Apanchane* (Water Owner), the female spirit of water who dwells in the river. In addition to addressing these spirits, the ritual dedicated offerings to the seed spirits (*xinaxtli*), who control the germination and growth of each crop in the field.

The center of activity was an altar on which the shamans had placed paper figures representing these seed spirits. The shamans made offerings before the figures and spattered the blood of sacrificed chickens and turkeys over them. Previously, women and girls had washed and dried the tiny clothes that I had seen during the afternoon. At the close of the ritual twelve days later, the figures would be dressed and returned to a special wooden cabinet, where they would remain until the next year's ceremony.

Right: At a ceremony to protect village leaders, a Nahua shaman renders the altar sacred with incense. On the altar he has arranged paper cutouts of messenger spirits who will take the offerings to guardian spirits. A paper sun hangs above them. Below: A corn spirit figure, clothed as an unmarried female, is one of the seed images used in a Nahua crop fertility ritual.

Photographs by Paul Jean Provost



The Nahuas view the seeds as unruly children who must be coaxed and cajoled to stay in the village and do their work. The villagers keep paper representations of the seed spirits in a cabinet, along with tiny chairs, grinding stones, sleeping mats, and other comforts so the spirits will not be tempted to run away. Copal incense is burned and young girls are assigned to dance before the cabinet from time to time. Concern for the seeds culminates in the ritual I witnessed, when the images are given clean clothes and offerings of food, cane alcohol, animal blood, tobacco, music, and dance.

In the months that followed my first experience, I observed dozens of rituals featuring paper figures. The villagers' initial reluctance to reveal these activities to me, Antonio explained, was because missionaries and civil authorities do not approve of the old rituals and have tried to put a stop to them. The Nahuas thus conceal their activities—so effectively that one Mexican schoolmaster, teaching in local villages for twenty-seven years, had no idea that any ancient rituals survived or that paper figures were the main component of Nahua observances.

The use of paper as a sacred substance has a long history in Middle America. A stone paper beater discovered on the Pacific coast of Guatemala dates to 1000 B.C. Virtually every sixteenth-century Spanish chronicler of Indian society wrote about the numerous uses for paper, particularly in religious observances. Fray Bernardino de Sahagún, for example, recorded that before Aztec traveling merchants went on a dangerous mission, they cut pieces of paper into banners with forked ends.

> And thus they did paint the paper: they gave it lips, nose, eyes. It resembled a man. Thus they did make a representation of the fire [god]. Then they cut the [paper] which pertained to the earth [god], whom they called *tlaltecutli*. He was bound about the chest with paper; also with the liquid rubber they gave him lips, nose, eyes. He also resembled a man.

The ritual continued as the merchants painted several more deities on cut paper and laid them out in a courtyard. Then, standing before the fire, they beheaded sacrificial quail and drew their own blood by piercing their ears and tongues. They offered the blood to the fire and then spattered it upon the papers. In another instance, Sahagún writes:

> Those who, through the advice of their astrologers, were able to ward off a disease, chose a very lucky day, and on that day burned, in the hearth of their homes, a great many papers on which the astrologer had painted with *ulli* [gum] the images of all those gods who, they guessed . . . had helped them to ward off that illness. The astrologer [after thus painting them] handed them to the man who made the offering, telling him [the name of] the god painted thereon; the man then burned all the papers; they gathered the ashes and buried them in the courtyard of the home.

Paper was also used to make holy books, adornments for statues, clothes for priests impersonating deities, and sacred banners and flags. Slips of paper accompanied the dead on their journey to the underworld and were burned in great numbers as offerings to various deities. The Aztec demand for paper was enormous; according to tribute lists, conquered towns sent millions of sheets and rolls of paper to the Aztec capital each year.

The inner bark (or bast) of fig and mulberry trees and the leaves of the maguey plant were the chief materials from which paper was made. Hundreds of towns and villages in Mexico engaged in its manufacture, and many present-day place names reflect this ancient activity. In the state of Morelos, for example, are Amayuca (Amayocan), which means "place where paper is made," and Amatitlán, which means "place of many paper trees or of much paper." These names are formed from *amatl*, the Aztec word for paper. Because of the connection between paper and native religious practices, the Christian Spanish conquerors began systematically eliminating traditional papermaking. Possession of paper was sufficient grounds to arrest a person for idolatry. Papermaking rapidly declined, and by the nineteenth century, most students of pre-Hispanic civilizations assumed that it had vanished.

Then, in 1900, an American anthropologist named Frederick Starr, traveling in the remote mountainous region of eastern Mexico, found Otomí Indian villages in which traditional papermaking had survived. He observed women extending fibers on boards using stone beaters resembling those uncovered by archeologists. He became the first Westerner since the early sixteenth century to witness and de-

cribe this process. Even more remarkable as his discovery that the paper was still eing used in religious rituals. Entering a mall shrine in one village, he saw an altar overed with paper images that had been prinkled with the blood of sacrificed ani- nals. "The most curious was cut into roups of human figures, some of which ad crowns and horns, or tufts of hair, pon the top of their heads. These were aid to be decorations for Montezuma, in hose honor a feast was given."

Subsequent research has revealed that Nahua, Tepehua, and, to a lesser extent, Totonac Indian shamans from the same egion also cut paper figures for ritual use, ut only the Otomís in the village of San Pablito, Puebla state, continue to make raditional bark paper. San Pablito sup- plies sheets of bark paper to the painters of olk images, who sell their colorful art- work in tourist markets. These paintings re called *amates,* another word derived rom *amatl.* In addition, several shaman ntrepreneurs from this village have been uccessful at selling samples of their cut paper figures in the international tourist narket. Shamans from other villages, however, almost exclusively use industri- lly manufactured tissue paper, which hey buy in the local markets. One Nahua haman explained to me that tissue paper is cheaper and preferable because it comes in colors.

Once I had witnessed a ritual, the Nahua shamans opened up to me and began to explain the identity and design of their paper shapes. The figures are three to ten inches tall and are cut with scissors. Most are anthropomorphic and front-faced, their hands raised at the sides of the head. Various distinguishing features are either cut into the body or protrude from the arms, head, or sides. Each shaman has a slightly different inventory of figures and style of cutting, but paper figures from neighboring Otomí and Tepehua villages are similar to those I collected among the Nahuas.

Paper figures can be loosely classified into five types. First there are those representing the major spirits—Sun, Earth, Stars, and Water—in their many aspects and manifestations. A second group represents disease-causing *malos aires,* or "bad airs" (*ejecatl* in Nahuatl), the souls of people who have died tragic or violent deaths. These spirits wander eternally, like predatory animals in search of victims. The seed spirits, which are responsible for the crops, make up a third category of paper cuttings. Fourth are the images of witness or intermediary spirits, which act as messengers between humans and major spirits. Finally, there are miscellaneous images used as altar adornments or in specialized rituals such as love magic.

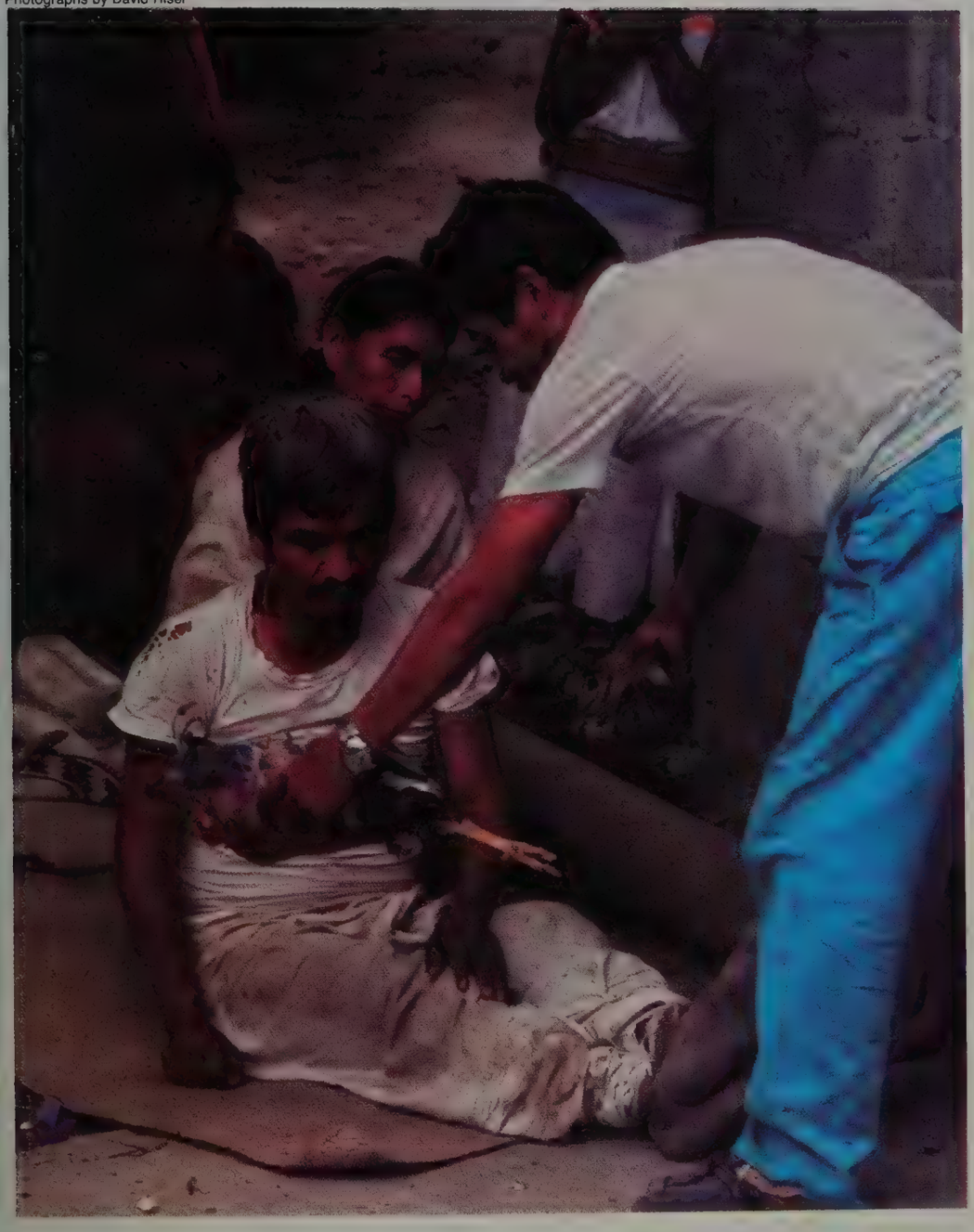
Paper figures are important in most rituals presided over by the shamans. A common ritual is a curing, or cleansing, designed to rid a patient and his or her surroundings of *malos aires.* Others involve disease prevention, crop and human fertility, harvest rites, life crises such as birth and death, and love magic. Rituals share in common a sequence of acts to rid the area of *malos aires,* to which is often added an offering to major spirits or their intermediaries. A ritual directed to ancestor spirits, for example, requires the cutting of paper figures of *malos aires* for the preliminary cleansing and of intermediary spirits who take offerings to the realm where the ancestors live. A small curing ritual may require only seven or eight figures, while larger rituals may involve up to five or six hundred.

On one occasion the local headman, Manuel, invited me to participate in a cleansing held to protect him and the other men who are village leaders from disease during their terms of office. By this time I had attended so many rituals that I was expected to help in the preparations. At Manuel's house, the shaman directed me and the other participants to gather the necessary offerings to the *malos aires* and various guardian spirits: tobacco, sacred herbs found in the forest, copal incense, raw eggs, cane alcohol, beeswax and tallow candles, cornmeal, and sacrificial chickens and turkeys. Expensive bottles of soft drinks and beer, purchased at a distant market, were also required. As we assembled the necessary offerings, the shaman took out a sheaf of paper and began to cut images of the appropriate spirits.

When all was prepared, the shaman bathed each chicken and turkey in incense smoke. Chanting to various spirit helpers, he broke the birds' necks and laid the birds on the earthen floor. (These were cooked and offered to the spirits later in the ritual.) The shaman then laid out on the house floor an altar composed of several paper images of *malos aires* and some of the offerings. He chanted over the fig-

Left: An Otomí shaman spatters paper figures and sacred herbs with sacrificial chicken blood. The chicken will be cooked and presented to spirits so that they may consume its essence. It will then be eaten by people in attendance. Below: To draw out spirits in the patient's body, the shaman rubs the patient with the chicken and a bundle of paper figures and sacred herbs.

Photographs by David Hiser



ures, imploring the spirits to accept the offerings and to depart from the village leaders' bodies and their surroundings. The shaman then formed a bundle of paper figures and altar adornments and rubbed it vigorously over the men while intoning, *xiahke! xiahke!* ("begone! begone!").

After replacing the bundled items on the floor, the shaman began a long chant. Swirling a smoking incense brazier, he dedicated the offerings to the *malos aires* and asked the spirits to leave the men and their families alone. After a while, he spread the tobacco, raw eggs, cane alcohol, cornmeal, and other offerings on the paper figures before him, enticing the spirits to come and feed on their respective images. Then repeating the command *xiahke! xiahke!*, he turned the paper figures over and violently ripped them to pieces. This final act was designed to disorient the *malos aires,* preventing them from finding their way back to the men. The spirits were thus forced to return to their places of origin.

The shaman repeated the procedure of making an altar and then destroying it at six additional locations: at the house entrance, on a trail leading from the house, at a crossroad, by the stream where the family bathed, at a prehistoric ruin believed to be a doorway to the underworld, and near the family fireplace, in which a guardian spirit was supposed to live. Each of these locations was cleansed of *malos aires* to rid the surroundings of danger and to protect the men on their daily rounds. The shaman made a final offering at the peak of a sacred hill, before images of witness and intermediary spirits, go-betweens who would take the offerings to the powerful guardians who would actually protect the men.

While he was cutting images of the *malos aires,* the shaman observed that these spirits were filthy and disgusting. In Spanish they are called *basura,* or "garbage." The shaman said they live in dank caves, tangled underbrush, or stagnant pools of water. He portrayed them with infectious spines or dirty matted hair. Several were cut with animal horns, linking them to the spirit *Tlauelilo* (Wrathful One), who is the Nahua equivalent of the Devil and is believed to rule over unclean animals. Another shaman explained, "These are bad spirits; they make you sick, they ruin your corn, they kill your children." Any disaster, from crop failure to barrenness to malaria, is linked to these malevolent spirits of the dead. Sorcerers send misfortune in the form of *malos aires,* and mental disorders are also attributed to them. Many spirits are attracted by people's misbehavior. Gossip, anger, slander, and acts of sorcery draw them into the village, where they seek out victims at random. Thus, an individual's bad deeds endanger everyone.

The names of *malos aires* are revealing: *Tlasole Ejecatl,* Filth Wind; *Mictlan Tlasole Ejecatl,* Underworld Filth Wind; *Apantlasole Ejecatl,* Water Filth Wind, and so on. People the world over safeguard their cultural and social systems by identifying agents of disruption with filth and dirt—in short, pollution. Examples of polluting behavior in Western culture include incest, which is a disruption of the kinship system, and, on a more mundane level, the placing of a tennis shoe on the dining-room table, which offends the order of a house-

A patient's image is bathed in copal incense smoke to strengthen his spirit and make him healthy. The Indians believe that the smoke makes a paper image sacred and carries the message of the ritual upward.
David Hiser

hold. The *malos aires* are Nahua personifications of pollution. They are associated with misbehavior and so represent violations or disruptions of social norms, elements of disharmony in village life. The *malos aires* are former human beings who have turned against their living kin. Since they are attracted to a village by the misbehavior of the inhabitants, they are pollutants put there by the very human beings upon whom they prey.

Initially I collected samples of the paper figures to get an idea of the extent of the spirit pantheon, but as the collection surpassed 1,000 specimens, I realized the futility of the task. Almost anything can have a paper image made of it. Examples include plants, animals, human beings, musical instruments, houses, fire, and water. A seemingly endless number of spirits are propitiated in rituals. In addition, any single spirit may have multiple manifestations with contradictory characteristics. The Nahua Earth spirit, for example, is represented in rituals as *Tlali,* Earth; *Tlaltepactle, Tlalticpac, Tlalticpa,* all aspects of Earth's surface; *Axcatlaltipatli,* Earth as a Whole (literally "Belongings of the Earth"); *Tlalimematsi,* Wife of the Lord of the Earth; *Tlaxwewentsi,* Lord of the Earth; *Tlaltetata,* Father Earth; *Tlaltenana,* Mother Earth; *Tlalsisme,* Aunt of the Earth; *Tlaltepa,* Earth Place; *Semanawak Tlaltentle,* Edge of the Earth; *Moctezuma,* Devouring Earth; and so on. Shamans stress that these are the same spirit, even though *Tlaltenana* is a benevolent provider while *Moctezuma* is a monster that devours dead bodies and leads the *malos aires.*

The multiplicity and contradictory nature of spirits in the Indian pantheons led explorers to disparage the Indian religions. After a visit to the Otomís, Victor Von Hagen wrote, "Such is the lamentable decadence of Mexican paper," while Dard Hunter observed, "Paper among the Otomís does not concern the intellectual." Lenz commented, "In many regions it was not possible to eliminate all of the vestiges of idolatry that even now exist in the aboriginal mentality." With the pantheon of spirits changing from one village to the next and even from one shaman to another, modern ethnographers as well are tempted to describe the native religion as polytheistic and leave it at that.

But the design of the paper images suggests that there is a unifying inner structure in Mesoamerican Indian religious thought. At the center of each image is a human figure set in its characteristic stance—a feature that does not vary with the cultural affiliation of the shaman who cuts it. Shamans add to this core a series of markers that define the character of the spirit being depicted. These include color, headdress, clothing, shoes, hair, spines, and, in the case of seed spirits, fruits and vegetables. This form of depiction allows the viewer to distinguish specific individuals in a group of spirits while simultaneously providing continuity among them.

In my view, the religion is not polytheistic, that is, based on a belief in a number of individual spirits each with a name, personality, range of power, and specific domain. Instead, the underlying similarity of the paper figures leads me to embrace a suggestion made by the late Eva Hunt, an authority on Mesoamerican religions, that these religions have a pantheistic quality. In pantheism (a term usually reserved to describe certain Eastern religions) the entire universe is sacred, and the spiritual entities that constitute the pantheon are but transitory manifestations of the great unity. Everything is related, and those things that appear to be separate—even opposite—are actually the same thing. The earth, for example, is not a solitary spirit that makes crops grow, but an aspect of a greater whole, containing within it all of the complexities and contradictions of the universe.

Through their rituals and paper images, the shamans temporarily break the unity into manageable segments in order to restore harmony and balance between humans and the powers in the universe. Since the Nahua are horticulturists, the spirits conceived and given form are typically connected to cultivation—spirits associated with aspects of the earth, water, sun, seeds, and of diseases that rob both plants and people of their vitality. When I puzzled over why the paper figures were so similar, Antonio simply replied, "Because they are the same thing." I now realize what he meant: the paper images are the same spirit in different guises.

The earth is inextricably united with everything else, but temporarily becomes a separate entity when being addressed in a ritual or when a shaman cuts its image out of paper. Furthermore, when asked about this spirit, the shaman will describe its nature as it appears in that particular context or paper image. Thus, on different occasions, Antonio described the earth as a beneficent provider, a bringer of rain, a devouring monster, and a leader of *malos aires.* When I questioned him about this he replied, "The earth is all these things."

The unity that lies at the heart of this Indian religion partly reveals itself amid the color and diversity of the ritual practices, the complex pantheons, and the stacks of blood-soaked paper images. When I asked the Nahua shamans about this unity, they replied that *Toteotsi* (Our Honored Deity) was the one spirit, and pointed to the sun. The sun, which occupies a similar position in Otomí and Tepehua pantheons, is a creator deity that looks down upon earth from its place in the sky. When portrayed anthropomorphically in cut paper, the sun exemplifies the principles of action, movement, and power. Thus, the underlying unity appears to be the principle of animation itself; that which imbues objects, animals, plants, and people with a vital life force.

One Nahua word for spirit, *tona,* literally means "heat" or "sun," as if the sun is the source of the animating principle. The Tepehua word for their religion is *Halakiltúnti,* The Moving of Things. And the pre-Hispanic Aztecs, who conceived of the current, human era as the fifth in the history of the cosmos, called it *Naui Ollin,* or Four-Movement. This name, usually linked to their idea that our era will end in earthquakes, may also underscore that activity is the organizing theme of our age. As a symbol of an animate being, the human figure, which is the core element in the shamans' paper figures, provides a visible representation of this principle of animation, affording us a glimpse of the cosmology of the great city-states of ancient Mesoamerica. □

After Christopher Columbus

by John R. Alden

The 500th anniversary of Columbus's landfall in the New World is almost upon us. Although he was indubitably preceded by others, Columbus initiated the European colonization of the Western Hemisphere and for practical purposes should be credited with its discovery. But the upcoming quinquecentennial celebrations seem destined to reopen a number of other longstanding issues. The first will be the question of where Columbus actually landed. More generally, historians will want to reexamine the progress and consequences of Spain's exploitation of these remarkable new lands.

Two new books mark the opening salvos of what promises to be a fascinating series of debates. *In the Wake of Columbus* contains seven scholarly papers arguing what is delicately called "the Columbus landfall problem," an issue that even now engenders controversy. *Spanish Sea*, by contrast, presents a thorough, careful description of the Spanish exploration and colonization of the lands around the Gulf of Mexico. Both are worth reading.

It may come as a surprise to hear that there is any dispute about where Columbus first landed. The nautical historian Samuel Eliot Morison said it was Watlings Island, and the people of the Bahamas felt confident enough in that identification to rename Watlings "San Salvador," the name with which Columbus christened his landfall. But if the contributors to *In the Wake of Columbus* agree about anything, it is that there are a fistful of reasons to question Morison's choice.

The source of this modern-day confusion is simple. The original journal of Columbus's first voyage has been lost, and the only document left to work with is an abstracted copy made by the Spanish chronicler Bartolomé de Las Casas during the first half of the sixteenth century. This summary of the *Diario de Colón* is generally considered reliable, but Las Casas did omit some sections of the original document and edit others. In the end, there is no way to determine just how accurately he reproduced the original ship's log. Subsequent transcriptions have only magnified the problems that interpreters of the *Diario* face.

IN THE WAKE OF COLUMBUS, edited by Louis De Vorsey, Jr., and John Parker. *Wayne State University Press, $25; 232 pp., illus.* SPANISH SEA, by Robert S. Weddle. *Texas A & M University Press, $34.50; 457pp., illus.*

To clarify the impact of these issues, it is necessary to understand how investigators attack the landfall question. Columbus's log has a fixed starting point in the Canary Islands and a generally agreed-upon landing at Cuba's Bahia Bariay; in between, is an elaborate but frustratingly vague description of a meandering sail through the Bahamas. Thus, the location of San Salvador can be identified by working forward from the Canaries, backward from Cuba, or from details in the descriptions of the various Bahamian islands that Columbus visited. Unfortunately, each approach produces a different answer.

The confusion springs from several sources. First, there are internal contradictions in Las Casas's version of the original log. Where he has written *las isla*, for instance, we cannot tell whether the voyagers saw islands (the plural article) or an island (the singular noun). At another point, Las Casas seems to have miscopied *sueste* (southeast) as *gueste* (west). Is the extant punctuation Columbus's own, or does it come from Las Casas? Each of these issues introduces uncertainty into the sequence of events recorded in the *Diario de Colón.*

There are also problems with translation. After all, the Admiral of the Ocean Sea was little more than a partly educated sailor from Genoa, and his fluency in Castilian Spanish is open to question. As a result, we don't really know whether he used the words *isla* (island), *isleo* (small island), and *isleta* (tiny island) consistently and to make meaningful distinctions. And what about *punta* (point), *angla* (wide cape), and *cabo* (cape); or *golfo* (gulf) and *canal* (channel)?

Finally, there are questions about the accuracy of Columbus himself. Although the president of the Leif Ericson Society is hardly impartial, there is some truth to his observation that Columbus "didn't know where he was going; and when he got there, didn't know where he was; and when he returned, didn't know where he had been." This confusion went beyond Columbus's failure to recognize that he hadn't found Asia. On more than one occasion he sounds thoroughly lost. He rarely mentions details such as whether he approached the northern or southern end of an island, and he unquestionably exaggerated in calling one harbor "large enough for all the ships of Christendom."

A smattering of hyperbole seems forgivable, for Columbus had every reason to magnify the importance of what he had found. But the possibility of systematic exaggeration gives students of the Columbian voyage altogether too much latitude in interpreting the evidence of his log.

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These problems and a host of other esoteric disputes—whether San Salvador or Grand Turk is shaped more like a bean pod, whether Columbus mistook the faint star Alfirk for Polaris, how far one could see from the *Santa María*'s crow's nest, or the distance an Arawak Indian might paddle a canoe in a day—make the great landfall debate entertaining indeed.

There are not many answers to be found in this book. But because of its many historical, linguistic, geographic, ecological, navigational, and anthropological complications, the issue of where Columbus first set foot on the New World proves a fascinating one. There is much to be learned from the glorious can of worms that *In the Wake of Columbus* opens, and the book certainly offers an enjoyable way for landlubbers to begin their exploration of the Bahamas.

For many people, however, this sort of debate seems immaterial. Columbus unquestionably found land, and what really matters is that within a few score years the Spanish had destroyed the world they encountered and were creating something new. For readers interested in the results, Robert Weddle's encyclopedic *Spanish Sea* offers a more attractive venture.

Weddle's book is a narrative history describing Spain's effort to explore and colonize the shores of northeastern Mexico and America's Gulf Coast. He begins with the initial penetration of the Gulf of Mexico—the titular Spanish Sea—in 1508, and with Ponce de León's discovery of Florida in 1513. The Spanish lost interest in these northern lands, however, when Hernández de Córdoba (commissioned for the voyage because "he was very able at kidnapping and killing Indians") discovered Maya cities on the shores of the Yucatan. The riches of Mexico drew the invaders westward, and it was not until 1528 that a serious attempt was made to explore along the northern shores of the Spanish Sea.

But the long delay hardly mattered. Through an accident of ocean geography, Spain was able to monopolize this vast region for nearly two centuries. Primitive European sailing vessels could not breast the powerful current of the Gulf Stream, and they were forced to enter the Gulf of Mexico either by hugging Cuba's northern shore or sailing the length of the Caribbean to the 125-mile-wide channel between Cuba and the Yucatan Peninsula. Few foreigners were willing to risk such voyages in the face of the Spanish fleet.

Although the Spaniards were able to keep other Europeans out, they never did manage to settle this coast themselves. Expedition after expedition set off to

Greater Florida (a territory that encompassed everything from Georgia's Atlantic coast to Tamaulipas, Mexico) only to be driven out by starvation, hostile Indians, and disease. By 1685, when Weddle's study ends, America's Gulf Coast was still not colonized and the French and English were ready to move in.

Spanish Sea presents a catalog of reasons for this Spanish failure. Spain's expeditions were invariably undermanned and undersupplied. Every attempt seems to have been plagued by poor planning, weak leadership, chronic discontent, and official interference. Many of the vessels sailing this sea were unsound, and more than one sank in port. Hurricanes regularly destroyed ships carrying food, messages, and reinforcements, and the invaders' brutality inspired fierce aboriginal resistance.

Unfortunately, Weddle is primarily concerned with what, when, and where; he never analyzes this parade of failures to explain why. In essence, I would suggest the Spaniards failed because their efforts were parasitical. Instead of working to support themselves, they stole their food from native villages and did their best to enslave any Indian they could catch. Although the conquistadors were preternaturally brave when faced with a fight, most proved willing to starve before they would stoop to working the soil. They were able to conquer empires, but when they encountered tribal societies that could simply slip out of their way, the Spaniards were helpless.

This culture of conquest was not, of course, the Spaniards' only problem. The New World was underpopulated, and royal policies restraining trade kept the Mexican and Caribbean colonies chronically underequipped. When twenty-two French pirates could terrorize a town as important as Campeche, as happened in 1561, it is hard to see how the Spaniards could have mounted an adequate colonial expedition even if the political will to do so had existed.

Still, the tales of adventure Weddle relates are so gripping that in the end his lack of analysis hardly matters. Hernando De Soto's four-year exploration of the American southeast is only one of a dozen or so exploits that the author describes with candor, skill, and grace. Weddle recreates the excitement and challenge of this era, and *Spanish Sea* provides a fine introduction to a surprisingly neglected period in colonial history.

John R. Alden, an anthropologist and writer living in Ann Arbor, Michigan, is working on a history of the National Wilderness Preservation System.

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A Warrior's Last Stance

On a chilly afternoon this past October, a muscular Italian-American named Richard Liotta stood in a wood-frame mock-up of a Museum display case, naked except for an athletic supporter. Sculptor Karen Atta coated Liotta's body with vaseline, and using the same materials and methods that an orthopedic surgeon uses to set a broken limb, made an eight-sectioned mold of his body. For forty-five minutes an electric heater warmed Liotta and kept him from shivering as Atta and four assistants applied strips of gauze soaked in plaster.

When they hardened, the plaster molds were set aside. Later, they would be used to make a mannequin of a Kayapó warrior, an aboriginal Indian from central Brazil. The warrior is the seventh in a series of life-size figures being made by the art studio of Elliot and Ivan Schwartz for the Museum's Hall of South American Peoples, scheduled to open in 1988. The image of the Kayapó warrior required a model with a certain body type. The Kayapó are tall, strong people. "They are easily six feet, and some are taller," says Laila Williamson, anthropology exhibit associate. "They work outside and spend hours, sometimes days, in the forest on hunting trips." Richard Liotta, who is six feet tall and weighs 167 pounds, was a good physical match for the warrior. Besides, he says, "It's somewhat suited to myself as a person. There's really no difference between someone who grew up as a hunter in the Amazon and someone who grew up on the Upper East Side. The survival instincts are the same."

The Schwartz studio is housed on the second story of a red-brick walkup in the warehouse district of lower Manhattan. Here, Robert L. Carneiro, curator of South American ethnology, and Williamson coached Liotta in the role he was to portray. Because these Indians still live in a tribal society, much as they have for centuries, anthropologists have been able to live among and photograph the Kayapó. For half an hour, Carneiro and Williamson described to Liotta the habits and customs of the Indians and showed him pictures of a Kayapó warrior. Liotta's naked body was painted black except for his hands and feet, and his arms and neck were decorated with bands of red, white, and blue glass beads. Using photographs as a guide, Carneiro, Williamson, and Atta set Liotta in various positions, looking for one that was comfortable for the model, as well as anthropologically correct. "It might look good to us," Williamson says, "but if it's not comfortable to Liotta, then no Indian would be in that pose either."

The ideal representation would show the warrior erect, a wooden club in his upraised hands, ready to strike a charging enemy. But the restricted space of the display case prevented the use of this pose. An alternative was chosen—Liotta assumed a crouched position, the club to his side, just above his shoulder. (This stance, I suggested, resembled that of a baseball

At the American Museum

Middle Eastern Dance

Middle Eastern dance, often called belly dance, originated in prebiblical times and formed part of a group of religious rites that venerated motherhood and prepared women for the physical efforts of childbirth. On Sunday, January 5, at 2:00 and 4:00 P.M. the dancer Morocco will perform several Middle Eastern dances in the Kaufmann Theater. The program is free. For additional information call (212) 873-1300, ext. 559.

Paul Robeson: Man of Conscience

In honor of Black History Month, the American Museum and WNET/Thirteen will present a lecture on Paul Robeson, black actor, singer, and civil rights activist, and show the Academy Award-winning documentary *Paul Robeson: Tribute to an Artist*. Through the story of Robeson's life, this film examines attitudes and policies in this country toward people of color and toward dissent in the 1930s, '40s, and '50s. The program will take place on January 9, at 8:00 P.M. in the Main Auditorium. Paul Robeson, Jr., will introduce the documentary and answer questions from the audience. Tickets are

player squaring to bunt, but Williamson cringed at the idea. "We tried very hard to avoid any baseball imagery," she said.)

Two weeks later, Atta began putting the pieces of the mannequin together. The feet, cast from the mold in solid steel and covered with plaster, were placed on the floor; a cardboard square of Liotta's footprints, made while he posed, showed the exact positioning. The back half of Liotta's torso and legs, already cast in half an inch of plaster, was strung from the ceiling and lowered onto the feet. Polaroid photos showed the proper positioning. Atta plastered two steel rods protruding from the foot casts into the back of the torso and plastered the seam between the torso and feet. She repeated this process until all eight sections were assembled.

The warrior's height and build came from Liotta, and a North American Indian will eventually give the mannequin its face. It was Atta, though, who gave the Indian the specific characteristics of the Kayapó body. The torso, for instance, was filled in from the hips to the underarms. As Williamson explains, "The South American Indians don't have waists, as we do. They have a tubular body build." The mannequin's feet were redesigned as well; because the Kayapó wear no shoes, their toes are spread.

The finished warrior will be placed behind glass as part of a section on warfare. There for the next fifty years, perhaps even longer, he will crouch, his club raised to strike.

Marshall Schwartzman

free and can be ordered from the Department of Education. Please enclose a self-address, stamped envelope. One ticket per person, please. For additional information call (212) 873-1300, ext. 514.

Japanese Fantasy Dance Suite

The New York-based Saeko Ichinohe Dance Company will perform a program based on Japanese folklore and mythology. Among the creatures to be portrayed are the Kirin, a composite beast with a dragon's head and a stag's body, and the Baku, a fabulous beast that eats bad dreams. The program will take place in the Kaufmann Theater at 2:00 and 4:00 P.M. For additional information please call (212) 873-1327, ext. 559.

The Story Concert Players

Jamaican folk tunes, a Russian tale, and North American legends are all part of *Tales and Tunes from Around the World,* on Sunday, January 26. Christine Campbell and the musicians of the Story Concert Players will perform dramatic poems, chamber music, and folk tunes in this program designed for a family audience. At the show's conclusion, children may participate in a series of informal workshops about musical instruments, folk traditions, and the dramatic arts. Tickets for *Tales and Tunes from Around the World* are $3.00 for members and $5.00 for nonmembers and must be ordered in advance. The performance will take place at 10:30 A.M. and 2:30 P.M. in the Kaufmann Theater. For additional information please call (212) 873-1327.

Pioneers the History Books Forgot

Black people arrived with Columbus and explored with Balboa and Cortez. They became gold diggers, cattle branders, pathfinders, homesteaders, outlaws, and sheriffs. Women too were an integral part of western expansion. On Thursday, January 30, at 6:30 P.M.,two guest speakers devote a slide show/lecture in the Main Auditorium to the pioneers whom most people never hear about. This free program is presented in conjunction with the exhibition *Masterpieces of the American West* and is open only to members. Tickets must be ordered in advance. For additional information please call (212) 873-1327.

At the Hayden Planetarium

Halley's Comet: Once in a Lifetime, narrated by Leonard Nimoy, is back at the Planetarium. This Sky Show discusses how comets are formed and where and how to look for them. The second feature, *Hayden: The Golden Years,* not only takes viewers back through the past fifty years of astronomical discovery but also peers into the future to ponder what the next five decades might bring. The show is narrated by Charlton Heston. For time and price information please call (212) 873-8828.

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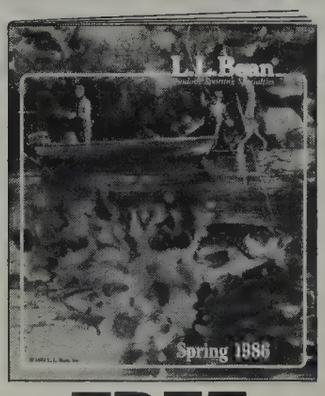

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A Telltale Wobble

The slight oscillation of a dim star led to the detection of its tiny companion object

by Stephen P. Maran

There is a strange, dim object orbiting a tiny star, known as VB8, about twenty-one light-years away from the earth in the constellation Ophiuchus. The object was first observed in December 1984, and astronomers have been trying to classify it ever since. It, too, has an unimpressive designation—VB8B. (VB stands for the late George Van Biesbroeck, an astronomer who spent much of his career at the Yerkes Observatory in Wisconsin and discovered the tiny star. The number eight means the star is eighth on Van Biesbroeck's list of stars. The second B indicates in astronomer's parlance that the object is the faint companion of VB8.)

Some astronomers believe that VB8B may be a red dwarf—the least massive of all types of stars. Other astronomers say the object is probably a brown dwarf. These are hypothetical objects presumed to have been formed, like stars, by condensation from interstellar clouds but, unlike stars, with a mass too light to ignite the steady nuclear burning of hydrogen in their centers that is a necessary stellar characteristic. Brown dwarfs are generally conceived of as objects that may be more massive than planets, but are even less massive than red dwarf stars. The suggestion has even been made that the object may be a planet orbiting the star VB8. There are arguments for and against each of these propositions, and those who do not work in the field may ask, what difference does the classification of the object make?

Red dwarf stars are believed to be the most numerous of all stars in our galaxy, so one more would not have great significance. Since brown dwarfs are hypothetical objects, detection of one would confirm the hypothesis. Planets, however, are an altogether different matter. If VB8B should be a verifiable planet orbiting a star—as our earth orbits our star, the sun—it would be the first extrasolar planet known to exist outside science fiction. Further, because planets are probably a necessary precondition for life, the identification of VB8B as a planet might add substance to the possibility of other faraway planets that might harbor extraterrestrial life.

Robert Harrington, of the U.S. Naval Observatory in Washington, D.C., a noted investigator of star positions and motions, found through precision measurements on telescopic photographs of the star VB8, made at intervals over the years, that it wobbles somewhat as it moves through space. This led him to suggest that the tiny star had an even smaller companion, whose slight gravitational attraction caused the star to revolve in a diminutive orbit around their common center of mass. Since the center of mass is itself moving through our Milky Way galaxy, the star is actually orbiting around a moving point, and the orbital motion appears to an observer on the earth as a wobble.

If the theory of a wobbling star sounds familiar, it is probably because many people have heard of Barnard's star (also in Ophiuchus), named for another deceased American astronomer. In the 1960s, a Swarthmore College astronomer announced that Barnard's star is wobbling as it moves, and he claimed that the wobbles are the result of two accompanying planets. That finding remains unconfirmed to this day, and some astronomers have specifically rejected it, but observations with the Hubble Space Telescope, to be launched on the Space Shuttle next August, are expected to settle the question.

Since the announcement about Barnard's star, astronomers have monitored the motions of many other nearby stars, on the lookout for telltale wobbles. Harrington, in particular, has reported finding several such wobbles of low-mass stars in the sun's vicinity, presumably caused by the presence of even lower-mass and hence fainter companions that might be brown dwarfs or planets or very-low-mass red dwarfs. However, prior to the December 1984 announcement concerning VB8B, no visible light or other radiation from any of these low-mass companions had ever been directly measured or photographed. Since the existence of the claimed planets of Barnard's star had also never been independently confirmed, the significance, if any, of Harrington's wobbles was an open question. Direct detection of the light from one of the tiny companion objects of a Harrington wobbler such as VB8 would, therefore, lend much support to Harrington's reports. That feat, for VB8B, was accomplished by three astronomers from the University of Arizona, in Tucson, led by Donald McCarthy, and was the subject of the above-mentioned December 1984.

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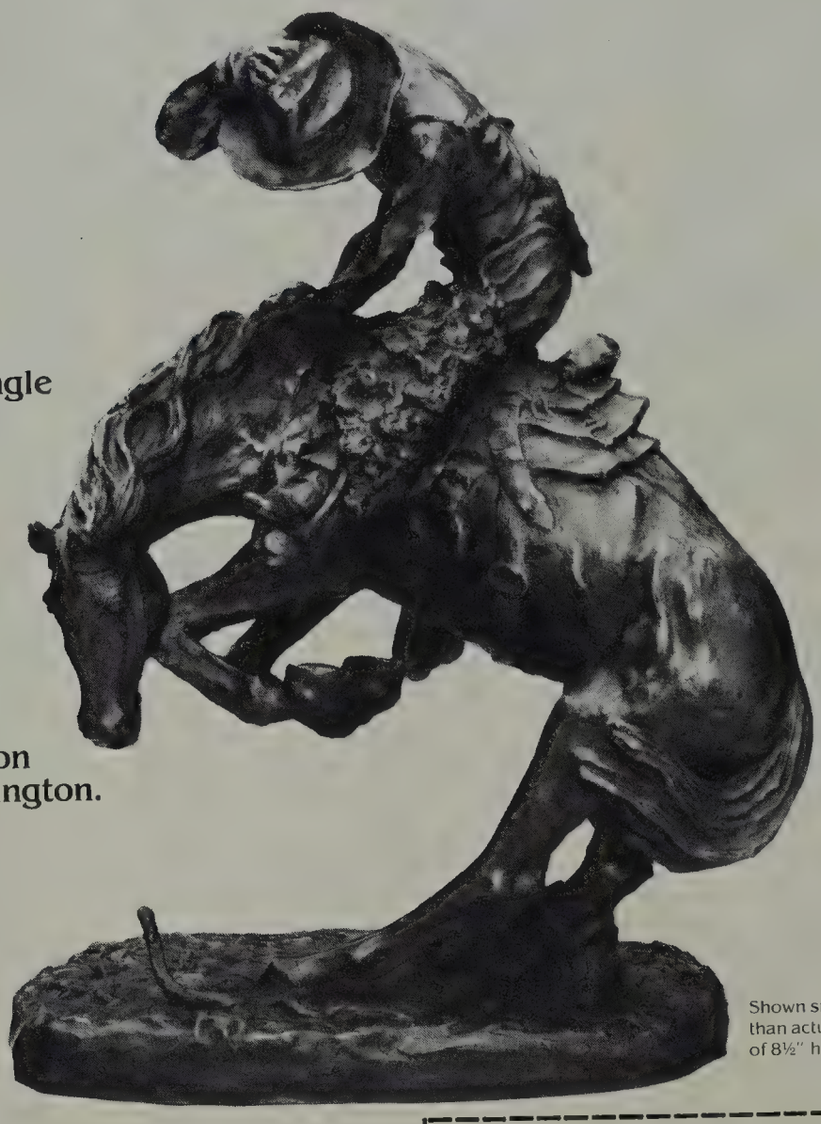

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announcement. The McCarthy team used a new technique called infrared speckle interferometry, which enables observers to find faint sources of infrared light that are located close to relatively bright stars. The speckle interferometry technique revealed a dim object next to VB8, which was glowing feebly in infrared light and was apparently too faint and too cool to be a star of any known type.

The McCarthy group concluded that they had detected VB8B, the companion object of VB8 whose existence Harrington had inferred from that star's wobble. Since the companion was too faint and dim to be a star, they called it a brown dwarf and claimed it was the first directly observed extrasolar planet. (Not all astronomers distinguish brown dwarfs from planets. If the object orbits a star, these astronomers would say the dwarf *is* a planet.) That claim, which attracted worldwide attention, led to a controversy over nomenclature.

At a January 1985 press briefing in Tucson, which I chaired, McCarthy defended calling VB8B a planet, pointing out that although the object is much more massive than Jupiter (according to estimates by other astronomers made since that briefing it may weigh in at seventy Jovian masses), it is denser than the planet and has about the same diameter—that is, it has more mass packed into a comparable volume. If it were put in Jupiter's place, VB8B would shine—in visible light—by the reflected light of the sun. Further, as seen from the earth, it would then appear to have about the same brightness as that of Jupiter.

If VB8B were a low-mass red dwarf star, it would then, by definition, shine as a result of nuclear reactions that would steadily burn hydrogen at its center for billions of years. But experts on theoretical models for low-mass stars, such as Francesca D'Antona of the Osservatorio Astronomico di Roma, in Italy, agree that VB8B is not massive enough to burn hydrogen in that way.

I once agreed with the initial assessment by McCarthy that the first extrasolar planet had been found. More recently, however, I have had the opportunity to explore the semantics of "planets" and "brown dwarfs" with experts from around the world who attended a meeting this past fall on brown dwarfs and I am no longer sure. The current trend in astrophysical semantics, I learned, is not to distinguish planets from brown dwarfs according to their respective masses or by whether or not they orbit a star or even according to whether or not they shine by their own light. A more appropriate set of definitions, according to an expert on star formation currently working in the Space Station office at NASA Headquarters in Washington, D.C., distinguishes between planets and brown dwarfs according to their respective methods of formation. Both planets and brown dwarfs are substellar objects, meaning they have smaller masses than the tiny red dwarf stars. However, brown dwarfs can be defined as substellar objects that formed, as stars do, by the condensation and fragmentation of interstellar clouds of gas and dust. Planets, in contrast, form by the accumulation of matter in the swirling disk that develops around a condensing star. Brown dwarfs are fragments of a cloud that may have formed many stars as well; a planet is an aggregation of matter from a disk surrounding a single star.

Philosophically, I prefer the Space Station expert's definition of planets and brown dwarfs to those previously used. But unfortunately, for those of us who were not present at the Creation, that semantic clarification does little to help resolve the case of VB8B, since we did not see how it was formed. Here help comes from Italian astrophysicist D'Antona who points out that brown dwarfs generate energy by compression under their own gravity for about 100 million years after their formation. They then slowly radiate their heat into space, cooling down for billions of years. From the measured temperature, reported to be about 2000° F, and the brightness of VB8B, D'Antona concludes that it may be a brown dwarf but is more likely to be a "transition object." The latter term, which she recently coined, refers to objects that are slightly more massive than brown dwarfs, but less massive than red dwarf stars. Red dwarf stars burn hydrogen at a steady rate, whereas transition objects, after shining by gravitational contraction for roughly 100 million years in the manner of brown dwarfs, eventually produce some nuclear energy. They are expected to shine by the combined effect of nuclear reactions (like a star) and the release of compression-generated internal heat (like a brown dwarf) for tens of billions of years thereafter.

If we can believe D'Antona, (and I know of no better authority), VB8B is neither a star nor a planet, and it may not even be a brown dwarf, although it is close to being one. However, even if the theoretical calculations on which her conclusion is based should be confirmed, the question of what VB8B is may remain unsolved. The reason is that the crucial factor in D'Antona's classification of VB8B is the approximately 2000° temperature of the object. The temperature, in turn, was determined from McCarthy's state-of-the-art observations of the intensity of light from VB8B, as received at two different wavelengths of infrared light. But, recent calculations by a group of planetary astronomers, also at the University of Arizona in Tucson, suggest that the atmospheres of brown dwarfs and such related objects as the above-mentioned transition objects are liable to be cloudy, like the atmosphere of Jupiter. The infrared light from these cloudy atmospheres would have complicated spectra whose intensities at the wavelengths of observation might reflect the chemical composition of the atmospheres more accurately than their temperatures. In other words, the 2000° reported temperature of VB8B may be wrong. If so, D'Antona's interpretation of VB8B as a transition object intermediate between a brown dwarf and a red star would have to be revised. If the VB8B is actually significantly hotter than reported, it might be an extremely low-mass red dwarf star, whereas if it is cooler than reported, it would more probably be a brown dwarf.

The age of VB8B is another complicating factor. If the object is younger than a billion years, it may well be a brown dwarf that hasn't had enough time to cool substantially. If it is much older than a billion years, it would have had plenty of time to cool and thus, if it is as hot as 2000°, it is more likely to be a low-mass star or a transition object rather than a brown dwarf.

Regardless of what VB8B may be, its detection by the McCarthy group stimulated immense curiosity among astronomers interested in brown dwarfs and the so-called missing mass. Studies of the Milky Way and other galaxies suggest that they contain far more mass than is seen on ordinary telescopic photographs—that is what "missing mass" refers to. That unseen mass, theorists say, must be present in the form of dim objects or vast numbers of subatomic particles probably of an as yet undiscovered type. Other scientists have proposed that the missing mass consists, at least in part, of brown dwarfs.

To look for more objects like VB8B and in order to see if they exist in sufficient numbers to account for the missing mass in our galaxy, astronomers have been searching selected regions of space with increased intensity since the December 1984 McCarthy announcement. As recounted at the recent meeting on brown dwarfs, however, all, or almost all, of these scientists have had no luck so far in the search. Of special note is the failure of an extremely sensitive electronic camera de-

veloped at the AT&T Bell Telephone Laboratories in Murray Hill, New Jersey, to find brown dwarfs in photographs made with a 158-inch telescope in Chile. That instrument should have detected the dwarfs at distances of dozens and perhaps hundreds of light years from the earth. Astronomers searching through the huge catalog of measurements made by the Infrared Astronomy Satellite, which surveyed the sky in infrared light during 1983, have thus far also failed to turn up brown dwarfs, although they would be present in the catalog if brown dwarfs are numerous enough to account for the missing mass. A further search for brown dwarfs in those satellite data is currently under way. A variety of other observational techniques have been employed by observers who have used ground-based telescopes in the search for brown dwarfs, with negative or inconclusive results except in one case.

The exception was a search conducted by Michael Hawkins, an astronomer at the United Kingdom Schmidt Telescope Unit in Siding Spring, Australia, which may have turned up a baker's dozen of purported brown dwarfs. He used a computer-controlled laboratory measuring instrument and a sophisticated computer analysis program to determine the brightness and positions of hundreds of thousands of images of faint stars on wide-angle photographs made with the 48-inch Schmidt telescope at Siding Spring. Comparing photographs of the same sky region made with this telescope in 1980 and 1984, the computer search isolated thirteen extremely red and faint objects, which seem to have relatively similar directions of motion, among the hundreds of thousands of images on the plates. Those thirteen objects, according to Hawkins, are brown dwarfs. This finding, which requires confirmation, surprised some astronomers who did not consider the photographic technique to be sensitive enough to reveal brown dwarfs.

Until that confirmation comes, VB8B will continue to excite the imagination of astrophysicists as the most likely known case of a substellar object located outside our solar system. The most exciting outcome of future research would, of course, be that VB8B or another object from Harrington's list is not a red dwarf star or a brown dwarf or a transition object, but a genuine planet!

Stephen P. Maran is a senior staff scientist in the Laboratory for Astronomy and Solar Physics at NASA's Goddard Space Flight Center in Greenbelt, Maryland. The opinions expressed here are his own.

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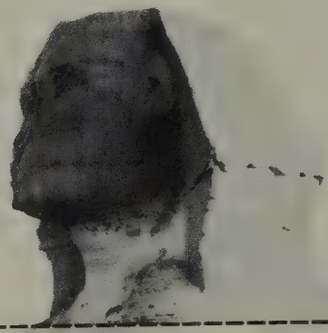

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Mars Is the One

by Thomas D. Nicholson

Four planets stretch out to the right (west) of the sun in the morning sky this month. Too bad we can't see them in daylight; their maneuvers would be interesting to watch. As it is, we will miss the first two, Venus and Mercury, entirely; they simply rise too late to be seen. But Saturn and Mars put on a fair show, along with the nearby star Spica, especially from the 4th to the 8th when the moon cavorts among them.

Saturn and Mars are the only planets we can see with ease in the January sky. Mars is still a bit dim, but its position relative to Saturn and Spica make it easy to spot. Mars is worth getting to know this month, as its relatively rapid easterly motion takes it closer to Saturn, which it passes in late February. But the best view of Mars will come in late spring and early summer, when its opposition (from the sun) brings it close enough to us to rival Jupiter in brightness.

As for Jupiter itself, we still have a fair shot at it during its waning days as an evening star. Look low in the southwest shortly after sundown. Unfortunately, it will be too low for viewing late in the month when it is about to make the switch from the evening to the morning sky.

Events in the calendar below are given in local time unless otherwise indicated.

January 1: Moonlight will welcome revelers home this morning and greet them after ten tonight, EST. The gibbous moon is four days past full, drifting across the border between Leo and Virgo tonight.

January 2: Earth is nearest the sun for the year (perihelion).

January 3: Last-quarter moon is in Virgo, climbing up the sky after midnight with the spring stars, just ahead of bright Spica.

January 4–7: It's worth getting up to see the morning moon parade past Spica and the planets Mars and Saturn, as it moves out of Virgo, through Libra and Scorpius, and into Ophiuchus. Spica is just behind the moon on the 4th. On the 5th, the moon is between Spica and Mars on the 6th between Mars and Saturn, and on the 7th, it passes below Saturn. The reddish star to Saturn's right is Antares in Scorpius. Compare its brightness and color to that of Mars.

January 8: The moon is nearest the earth (perigee) for the month and rises a little before dawn. Next time it's visible, it will be an evening crescent.

January 10: New moon is in Sagittarius, at 7:22 A.M., EST.

January 12: If you found the slim crescent moon in tonight's sunset sky, low in the late twilight glow, you should still be able to see Jupiter near it. If not, look for the crescent tomorrow night when it is higher and brighter.

January 13: Moonlight is ordinarily a problem in finding Comet Halley; its brightness masks the faint comet. But the crescent moon may be a help tonight, when it will not be bright enough to be troublesome and the comet is nearby to its right.

January 15: The crescent moon is a bit east of the vernal equinox tonight, below the two easternmost stars of the Square of Pegasus. Those two guides may help you fix the position of the vernal equinox among the stars.

January 17: First-quarter moon (at 5:13 P.M., EST) is directly south of Aries's bright stars as darkness falls. The moon is very near the junction of three constellations—Pisces, Aries, and Cetus.

January 19: Venus has been dawdling along all month only a few degrees to the sun's right. In the part of its orbit most distant from the earth, the planet moves easterly (to the left) somewhat faster than the sun. It passes the sun today (at superior conjunction) and enters the evening sky, but not until April will it become a conspicuous evening star. The moon is at apogee tonight as it moves from Aries into Taurus.

January 21: The Pleiades (the stars known as the Seven Sisters) are slightly to the right (west) of the gibbous moon.

January 22: Look to both the right and left of the moon tonight. Aldebaran is the orange star to the right, among the V-shaped stars of Taurus's face; Pollux and Castor, in Gemini, are the twin stars to its left.

January 24: Moonlight can't quite hide Pollux and Castor, which are very nearly in line with the moon and above it.

January 25: The full moon (at 7:31 P.M., EST) is in Cancer.

January 26–28: Leo hosts the moon on these nights. On the 27th, the moon passes above Regulus, the Lion's brightest star; on the 28th, it passes below Denebola, the end of the Lion's tail.

January 29: As the moon slips into Virgo today, it moves a few degrees above the autumnal equinox.

January 31: The moon rises with Spica, Virgo's bright star, for the second time this month. (January 4 marked their previous encounter.) Obviously, the moon has gone full circle around the earth since then but it is still two days behind its phase when it passed the star on the 4th. Mercury follows Venus past the sun today, also in superior conjunction.

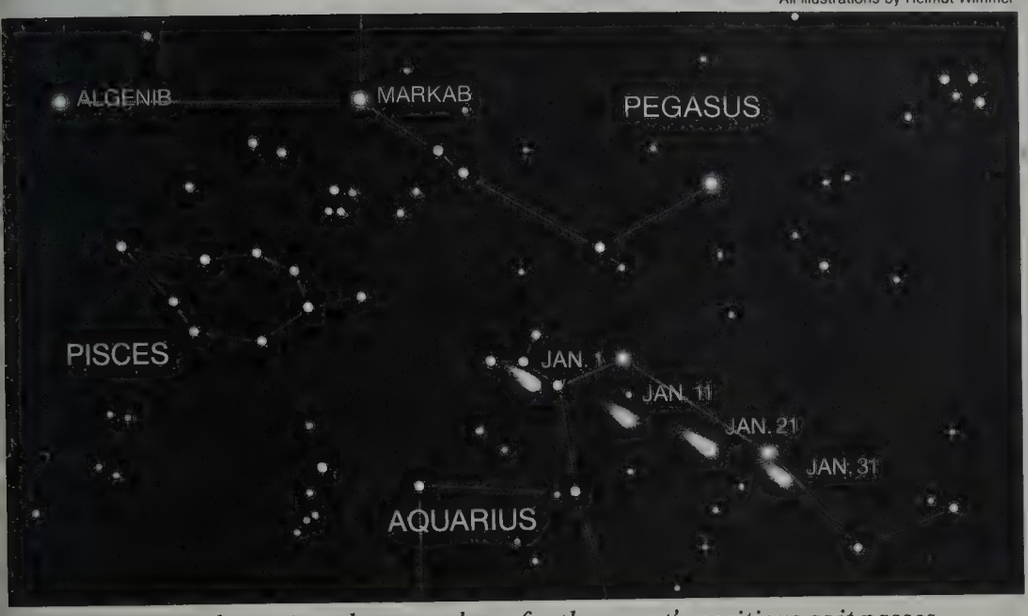
Halley's Comeback

The best opportunity to see Comet Halley from the mid-latitudes of the Northern Hemisphere is in January. The comet is in the sky during most of the evening, above the western horizon at sunset and setting after dark. It will not be easy to see, but if you want to see it you can, providing you know where to look and what to look for.

You will be looking for an object very much like a fuzzy star with a hazy cloud of light attached above. It will have a small, starlike, sharp center that is less than half as bright as the North Star. A faint halo of light surrounds the central region, a cloud of glowing gas about one-fourth as large as the full moon appears. The tail is above, an elongated patch of light about as bright as the Milky Way, perhaps three or four times as long as a crescent moon but much fainter, blowing out from the comet in a direction opposite to the sun, which is below the horizon.

Don't expect to see the object by simply glancing at the sky and looking around for it. It is so dim that you should use binoculars and choose your time and place carefully. There was a full moon on December 27 but by January 1 moonrise occurs about 10:00 P.M., so the western sky in the early evening will be without the moonlight that tends to obscure dim objects. New moon is on January 10 and by the 12th there will be a crescent moon in the sunset sky. That shouldn't cause any problem for a night or two, but by the 15th the crescent will be wide enough and bright enough to scatter a considerable amount

All illustrations by Helmut Wimmer



The illustration above gives the exact dates for the comet's positions as it passes through the stars of Aquarius. This diagram will be updated each month to let you know where Halley's comet will appear.

The position of the comet relative to the horizon is shown for three different times this month. That is, at 4:00 A.M., the comet is about on the horizon; at 3:00 A.M., it is a bit higher; and at 2:00 A.M., it is still higher.

of light in the west (exactly where you want to look for a faint comet) until shortly before the moon sets at about 10:00 P.M. The setting moon will make for a pretty sky, but it will ruin comet hunting, and the hunt will get more difficult throughout the rest of the month as the waxing moon brightens and stays up later.

The comet will be in the constellation Aquarius, low in the west after dark, below the Square of Pegasus. The diagram shows its position among nearby stars nightly, as it drifts slowly to the right (west) past them. It is best to search for it with binoculars (preferably 7 × 50 ones that provide enough magnification and a good, large-searching field of view). Use the Square of Pegasus, easily recognized from this month's Sky Map, to start from. After dark, Pegasus stands diagonally above the west, with its southwestern star, Markab, lowest, and its northeasterly star, Alpheratz, highest. Follow the line from Alpheratz to Markab downward to the right, about the same distance as that between the two stars. Then point your binoculars there and search slowly back and forth at the right, drifting up and down slowly as you search. Don't get discouraged; you may have to go back several times to start over again. But patience *will* reward you.

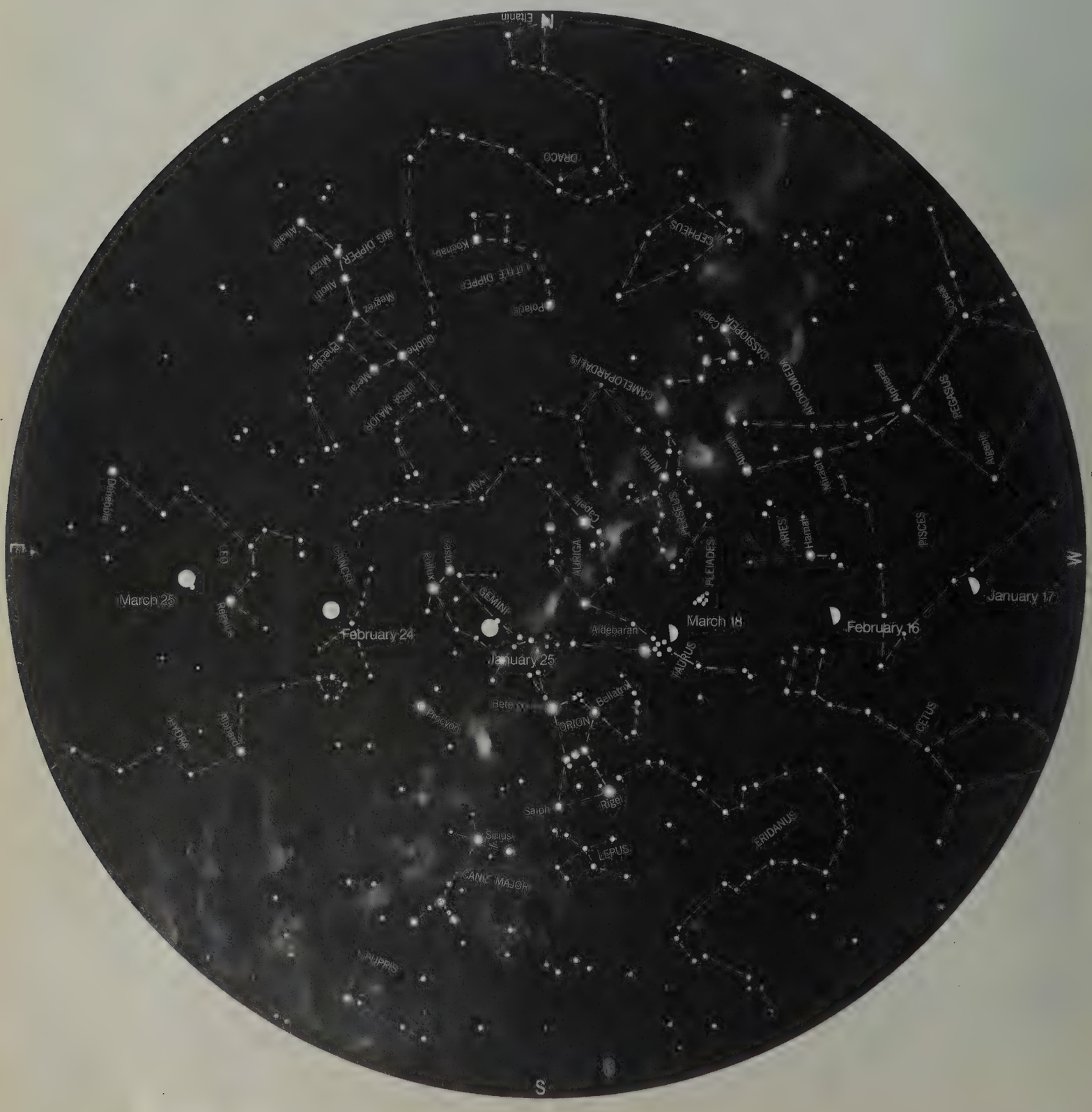
For practical purposes, you should look between January 1 and 15, although if you have already found the comet, experience may help you find it again later in the month. Moonlight is only one of the problems: weather, atmospheric pollution, and light pollution from populated areas are others. Two weeks ought to be long enough to wait out the weather for clear skies, unless we are awfully unlucky. But you will need clear or almost clear skies; partly cloudly ones aren't good enough when searching for a dim object.

Choosing an appropriate viewing location can materially enhance your chances, especially if you live in or near an urban area. First of all, choose a place with a clear view to the south and the west, no matter where you live; a place with no tall trees, buildings, or hills to obscure the western sky. Get to an area where there are no direct lights to impair your night vision adjustment, and give your eyes time (about fifteen minutes or so) to become

adapted to the dark. Your viewing site should also be chosen to avoid looking toward atmospheric haze or the glow of urban areas. Since you will be looking west, the best location should be west of urban areas, because urban haze usually drifts to the east and southeast, but that may depend on local weather conditions.

If the sky above you is exceptionally clear and dark, it may be possible to see the comet with the unaided eye, especially if you have located it first with binoculars or a telescope. It brightens slowly during this viewing period, and the tail should grow, nearly doubling in brightness and size from the 1st to the 15th of the month. On January 1, it will be more than 30 degrees high at the end of twilight and should be in good viewing position for two hours or so. Even on the 15th, we should have about an hour to see it after night begins. But by January 25, it will go down just as twilight ends.

The winter Sky Map shows the sky for January, February, and March from latitude 40° north at the evening hours given below. To use the map, hold it vertically in front of you with south (S) at the bottom and match the lower half of the map with the stars you see when you face south. As you face in other directions, roll the map to bring the corresponding compass direction to the bottom of the map. The stars move westward continuously during the night. By morning (before dawn), stars on the western half of the map will have set, those on the eastern half will have moved into the west, and new stars (those of the spring evenings) will have risen in the east. The map represents the sky at about 2:00 A.M. on January 1; 1:00 A.M. on January 15; midnight on January 31; 11:00 P.M. on February 15; 10:00 P.M. on February 28; 9:00 P.M. on March 15; and 8:00 P.M. on March 31. The map can also be used for an hour or more before and after the times given.



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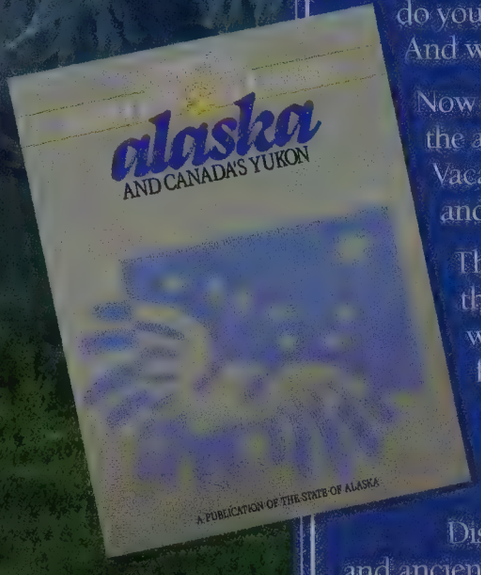

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A L A S K A

Nordhouse Dunes, Michigan

by Robert H. Mohlenbrock

The westerly winds blow across Lake Michigan, shifting the grains of sand that wash up along the eastern shore. Where the wind strikes a plant or another impediment, sand is deposited and begins to accumulate as a dune. An obstacle to the blowing sand, the dune continues to build, changing shape and wandering until vegetation becomes established on it and more or less stabilizes it. Sand dunes in all stages of development, from embryonic mounds to 150-foot ridges clothed in mature forest, can be seen in the Nordhouse Dunes, located about halfway between the Michigan towns of Manistee and Ludington. Part of Manistee National Forest, Nordhouse Dunes occupies more than four miles of shoreline, extending inland more than one mile. The undisturbed series of sand habitats found there includes, in addition to the dunes themselves, pools edged with rushes, and troughs where small flowering plants somehow survive periodic burial in sand.

Although no one knows the original source of the sand deposited in the Lake Michigan basin, apparently it was brought there by glacial action. The bedrock of shale, which at the shoreline is concealed below nearly 500 feet of sand, has been overlain by glacial "drift"—sand and other deposits—ever since a lobe of the Late Wisconsin glacier covered the area nearly thirteen thousand years ago. When the glacier receded, the sand deposits were at first inundated by a glacial lake. The water level fluctuated, however, with several successive glacial lakes forming and then receding, periodically exposing large amounts of sand, which was blown eastward by the strong winds. Today, sand on the lake bed continues to be washed ashore by wave action and distributed by the wind.

The dunes are accessible from the Lake Michigan Recreation Area to the north or from a parking lot near the end of sandy Nurnberg Road. From the parking lot, Nordhouse Dunes Trail leads to the shore of Lake Michigan, crossing from the older, stabilized dunes to the younger, ever changing ones. For three-fourths of its length, the trail winds up and down forested ridges, but the ground underfoot

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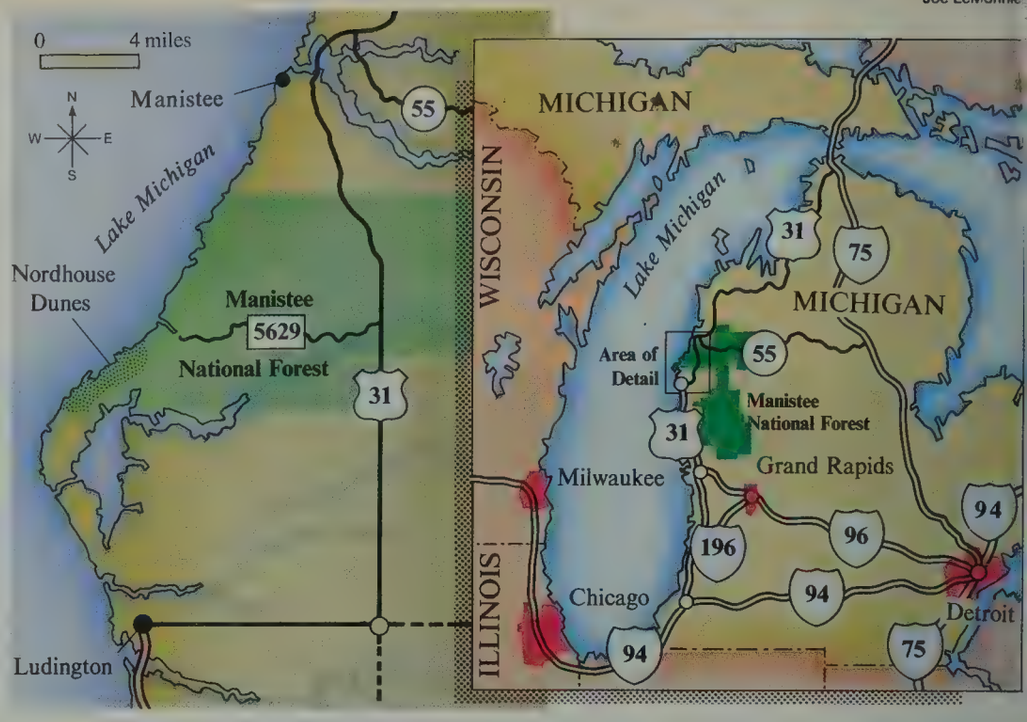

Nordhouse Dunes

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is sand and not the rich organic soil so common beneath other forests.

Where the sandy ridges are moist, there are well-developed stands of red maple, American beech, paper birch, large-toothed aspen, and red oak, punctuated by Canadian hemlock with its short, deep green needles. On the forest floor grow the ghost white stems of Indian pipe, topped by its single nodding flower. Indian pipe is one of a few flowering plants that completely lack chlorophyll, the green-pigmented compound involved in photosynthesis. As a result, this plant depends on the organic matter in which it grows for its supply of nutrients. Growing with the Indian pipe are other delicate wildflowers of the northern states, including the four-inch tall dwarf dogwood, trailing arbutus, wild lily of the valley, and starflower. The tiny but strongly scented wintergreen is abundant along the trail.

On drier, wooded ridges, the trees of the moister soil give way to oaks and pines. White, red, and black oaks predominate, but white pine, jack pine, and red pine are plentiful. Brian Hazlett, a Michigan botanist, has noted that there are great numbers of young white pines growing in the drier woods, which suggests that they will dominate this habitat in the future. Because of the reduced moisture, few wildflowers live beneath the trees.

The sand underfoot becomes progressively looser and the vegetation of the ridges sparser as the trail approaches Lake Michigan. Finally, the trail rounds a bend, affording the first glimpse of Lake Michigan and the shifting white sands of the open dunes. The beach proper, which extends inland from the lake for a few feet, is nearly devoid of vegetation because of the constant wave action from the lake. Where a line of driftwood has come to rest, however, a low ridge of sand parallels the lake bank. Known as the foredune, this low ridge develops when the wind strikes the driftwood, depositing sand on the windward side. The constantly enlarging foredune provides a place where seeds may become lodged. Although most flowering plants are unable to withstand the desiccating summer heat, two tiny annuals with succulent leaves have adapted to the arid conditions. One is a three-inch tall mustard known as sea rocket, while the other is a milk spurge that lies prostrate on the sand. Only annuals are able to survive in this habitat, because the furious winter storms that churn the sand would destroy the roots of any overwintering perennials.

In some places wave action creates breaks in the foredune, and the sand is blown through these openings and forms dunes behind known as blowouts. The blowout dunes are constantly changing and shifting as more and more sand passes through the openings in the foredune. Because the plants growing there are farther from shore, the flora of the blowouts is richer than that of the foredunes, but it is still relatively sparse.

During the summer, one of the most conspicuous plants is Pitcher's thistle, with its prickly leaves and beautiful lavender-pink flower heads. It is so uncommon in the United States that it is currently a

candidate for listing as an endangered species by the U.S. Fish and Wildlife Service. The thistle's dense covering of woolly hairs, which impede the evaporation of water from the leaves, enables the plant to avoid desiccation. A similar covering of densely matted hairs also protects the showy orange-flowered puccoon from the wind and sun.

As the blowout dunes build, perennial plants, many of them grasses, gain a foothold on them and serve as additional obstacles to the wind. Most efficient in stabilizing and actually building a dune is marram grass, *Ammophila breviligulata,* which sends out underground stems, called rhizomes, in a radial pattern beneath the surface of the sand. The stems and leaves of the grass provide areas where grains of sand become lodged. The radial growth widens the dune. At the same time, the marram grass continues to grow upward to lift itself above the sand, and the dune increases in height. Another grass that aids in the stabilization is sand reed, whose stiff, wiry leaves, stems, and roots resist the mechanical action of the wind. The extensive network of roots and stems below the sand surface binds the sand even after the plant dies.

Eventually the dunes build up into ridges that are receptive to colonization by trees. Once forest is established, some five hundred years after the dunes begin to form, the ridges become fairly permanent. Two conspicuous forested ridges, the Algoma and Nipissing, run north–south about a mile inland from the bank. Hiking trails follow their crests.

Throughout the complex of sand dunes at Nordhouse are troughs and depressions that have been carved out by the wind. Sometimes the depressions are gouged out to water level and become filled, forming dune pools. Sand-tolerant wetland plants find the edges of the dune pools suitable,

John Gerlach; Earth Scenes

Bunchberry, a dune forest wildflower, is related to the flowering dogwood.

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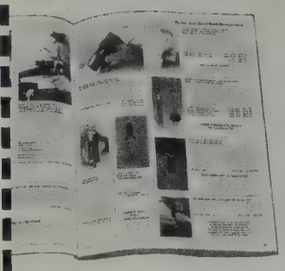

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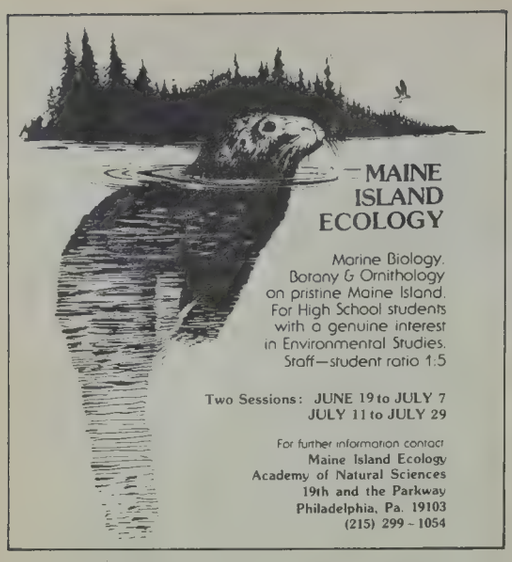

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The mushroom Russula *grows on the dune forest floor.*

and a community of rushes, bulrushes, and horsetails develops. The dry troughs are home to the glasswort, whose fleshy, jointed stems lack leaves, thus preventing excessive water loss.

A number of environmental conditions constrain the growth of vegetation in the various dune communities. The driving winds not only shape the dunes but literally sandblast living and dead trees. (As Henry Cowles, the pioneer plant ecologist at the University of Chicago noted at the turn of the century, mushrooms on the windward side of logs are virtually petrified because sand grains became embedded in the soft, growing tissue.) The sand itself—mostly large-grained, white quartz sand—is a porous substrate, poor in nutrients. Water percolates easily down through the sand, washing away what few nutrients there are and becoming less available to plant life.

The light in the dunes is intense, especially along the banks of Lake Michigan, where the sparse vegetation is surrounded by the reflecting sand. Exposure to strong light can kill chloroplasts, the plant cell organs responsible for photosynthesis. For protection, the leaves of most dune plants are covered by a thick cuticle (wax layer) or by hairs. Because of the paucity of vegetation and high exposure, temperatures on the dunes are more extreme than in surrounding areas—higher in summer and lower in winter. At the same time, the growing season is shortened because the sand does not heat up until late spring and cools rapidly in the autumn.

Despite the limitations of the environment, however, a succession of plant communities succeed in colonizing and stabilizing the shifting sands of Nordhouse Dunes. The process is constantly being repeated slightly westward, as new supplies of sand are added to the shoreline. As a result, the different stages of ecological change are arranged in orderly fashion across the landscape.

"This Land" highlights the biological phenomena of the 153 U.S. national forests. Robert H. Mohlenbrock is distinguished professor of botany at Southern Illinois University at Carbondale.

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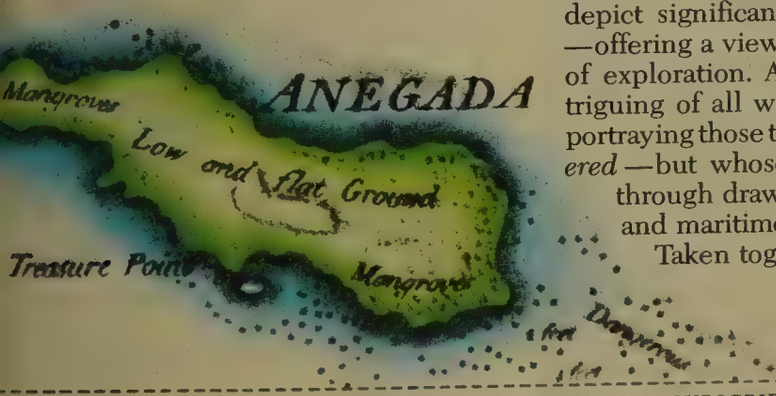

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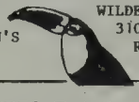

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Photograph by Art Wolfe

These two practitioners of the sweet science were found by photographer Art Wolfe not far from the Eureka weather station on Ellesmere Island, the large, cold, mainly uninhabited piece of Canada that reaches more than two hundred miles past the Arctic Circle. Unlike most of their relatives, arctic hares are gregarious, clumping into packs that can include as many as several thousand individuals. Bush pilots claim to have watched vast seas of them massed on the tundra.

Why they pack together is only one of the behavioral mysteries that surround arctic hares. For much of the year, they spend hours at a time crouching motionless on the snow, their thick white fur making them nearly invisible. Come springtime, mating commences. Some spring! When Wolfe shot this photograph last April, the temperature was thirty below. Some mating! The animals begin by standing up on their hind legs and taking swats at each other, males against males, females against females, and males against females. (Or so ethologists think: It's hard to get close enough to an arctic hare to discern its sex.)

"They'd box for sixty or seventy seconds," Wolfe reported, "slugging away but with their heads to one side so they wouldn't get hurt. It really looked silly. When they weren't boxing or sitting, they were running all over creation, chasing each other."

What happens after the boxing is not well known. Wolfe never saw any actual mating, and neither did most of the naturalists who have made the trek to Ellesmere Island. There are reports that the creation of little arctic hares is accompanied by violent frenzies. But verification of this, and much else about this species, awaits a visit by a biologist with pluck, determination, and many layers of thermal underwear.

Charles C. Mann

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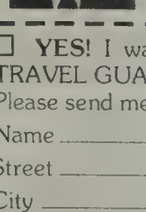

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The Real Thing

What are the criteria for preserving an authentic culinary heritage?

by Raymond Sokolov

For the entire time I have paid attention to food, the cry of every serious person in the field has been "authenticity." Surrounded by bogus adaptations and substitutions for classic and traditional foods, two generations of writers and chefs have battled for the real thing.

They have battled against ersatz ingredients and distorting processes in industrial products. They have campaigned, often in violent language, against recipes and restaurants that falsified our culinary heritage. The best of them spent their lives promoting authentic food ideas by publishing authentic recipes and insisting on authentic ingredients.

No one writing in the English language has fought harder and more intelligently for gastronomic authenticity than Elizabeth David. For forty years, David has been leading a crusade with her pen, in cookbooks that brought the real food of France and Italy, as well as her native Britain, within the reach of everyone. And since the early fifties, she has also pursued this mission as a journalist in various British publications. Her articles have now been collected (*An Omelette and a Glass of Wine,* Viking Press), and while they range widely across many areas, from the arcana of sardine preservation to a vivid account of the white truffle market at Alba in the Italian Piedmont, these still-important essays achieve an unacknowledged unity as an investigation of authenticity in the kitchen.

I think I may be making David sound something of a tedious caterwauler, but a brief glimpse of her method, as she lets fly at bogus mayonnaise, should remove any impression of shrill pedantry.

In "The True Emulsion," which appeared in *The Spectator* during the summer of 1962, she begins: "With the mayonnaise season in full blast, once more the familiar complaints about bottled mayonnaise and salad creams are heard in the land." Now if you have missed the buried allusion here to the cooing of turtle doves in the Song of Songs, it should still be obvious that the lady is mocking food purists at the same time that she joins them in deploring bottled mayo. For David it is not enough to repeat an old grumble. She examines it and finds legal, historical, and social causes for the abomination.

False mayonnaise predominates on English tables not because people are too lazy to make the real thing but because they actively prefer the fake. Why should this be?

David shows how food experts had been misleading the public since as far back as Mrs. Beeton in 1865. But the *coup de grâce* came in 1906, when the renowned chef and author Herman Senn revised Beeton and substituted two recipes, each wrongheaded in its own way. The first, although basically correct, called for more than two cups of olive oil, a disconcertingly huge amount, especially considering "the national English fear and dislike of olive oil." This, David argues, encouraged cooks to choose the preposterous second recipe, a sort of custard including plenty of milk. "By the thirties," she writes, "there was already a vast public brought up in the belief that mayonnaise was a sauce which could only be produced in a factory, which contained no olive oil—and tasted mainly of acetic acid. And that is what the great majority of people have come to expect when they see mayonnaise announced on a menu. It is not unnatural that they should be suspicious and indignant when confronted with the authentic sauce."

So, if you are Mrs. David, you speak out to combat the historical corruption of public taste; you decry a flawed system of labeling laws; and you wring your hands over ingrained English indifference to the actual ingredients of foreign dishes whose exotic names are blithely attached to any-

A Matter of Taste

ning that the chef or the manufacturer leases.

It would appear that we have settled the natter of authenticity. Unfortunately, uthenticity is as slippery a notion as hap-iness. Everyone (or almost everyone) is or it, but it is hard to get people to agree n what it is.

Perhaps you are thinking that an au-hentic dish (or recipe) is one honored by ong tradition in a settled cultural milieu. But this implies that an authentic recipe is he one preferred by most people in its ountry of origin. And yet this test of opularity (in the dish's native region) is ot at all what food experts or folk of efined taste would probably say was deci-ive in establishing a recipe for, say, the uthentic potato chip.

Surveys show that Americans prefer lightly rancid potato chips to fresh, be-ause they have always eaten commercial hips "aged" in the bag. You and I, of ourse, will not settle for anything less han hand-cut chips that we deep fry in resh lard and then consume immediately.

If you have ever made your own potato hips, with lard or vegetable oil, you will now how different they are from those roduced in factories. But perhaps you bject to the example. You want a case where popular taste has not been cor-upted by technology, but one where dis-greement arises among lifelong users from the same culture.

Look no further than the American Southwest. Texan chiliheads abhor beans; New Mexicans routinely put them in their version of chili. Similarly, each village along the French Mediterranean coast has its own "authentic" mixture of fish for its own "authentic" bouillabaisse.

But aren't these really distinct regional variations, each authentic for its town or state? If so, to what size must we whittle down our definition of region without al-lowing free rein to dozens of equally au-

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thentic, neighboring recipes for dishes all bearing the same name?

There is, in fact, no limit to this. In my family, people disagree about the authentic way to make dishes handed down from the same older relative. And I myself waver frequently between the versions, which must mean that even an individual is too large a cultural unit for determining authenticity.

So what should the inquiring gastroethnographer think when an informant, perhaps his Aunt Betty, tells him how she makes apple pie? How can he be sure that the old gal is not passing off some bogus flapdoodle on him just for laughs? Or because she doesn't know any better.

If this fieldwork were taking place as part of the first scientific contact with a hitherto isolated people (let us call them the Mem!tomos), the ethnographer would want to ask around the village a bit and see how the informant's pie matched up with others. If they were all the same, he would clearly have found out what an authentic pie was. But if they were only similar; some had top crusts, some had cream added to the apple mixture, some had only butter in the crust, others only margarine—but all of them had a circular crust baked with apple slices on top—then he would have to decide which features were fundamental and which were variations or extra fillips. Otherwise it would be impossible to publish just one recipe and assert that it, with certain possible variations, was the authentic apple pie of the Mem!tomos. The careful ethnographer might want to poll all the cooks and ask them what they thought was the essential pieness of their pie.

This process of taking an average or Platonizing an ideal recipe from the raw data of individual cooks' testimony is not, however, what has typically occurred in even the most scrupulous studies of regional or ethnic foods. In every case I know of, from true anthropological work with preliterate people to the reportage conducted in France by Curnonsky, only one or, at most, a very small number of practitioners were consulted. Then their recipes were written down and acquired the prestige we attach to the "authentic" practices of the naive.

Publication leads to codification. From many Homers, each singing the traditional epic-formulaic material in his own way, the Greeks passed on only one. Once the *Iliad* and the *Odyssey* had been transcribed, they became official texts, memorized and studied to the point of stultification by the time of Theocritus.

Something like that has been happening in the 150 years or so since the great early nineteenth-century chef Carême codified his magisterial practice. The grand dishes of the nobility were frozen, given standard form. In other words, *haute cuisine* acquired criteria of authenticity that were modified—mostly simplified—but which remained essentially unaltered until twenty years ago. In this century, the process of codification—one almost wants to say licensing—was extended to the regional cooking of France and, gradually, to ever more remote localities and foods: the Mekong Delta and its fish, India and its desserts.

Writing down these exotic food ideas has been and continues to be an important and laudable activity. Without it, whole cuisines would vanish as the world inexorably homogenizes. But authentication is a procrustean bed; it lops off the messy edges of cooking. Cookbooks not only preserve; they overdefine and delimit cooking when they set forth a single version of a dish and, explicitly or implicitly, suggest that other versions are spurious.

Mrs. David, for instance, ever the evangelist for the foods of the Mediterranean, where she formed her basic tastes, assumes without discussion that the authentic mayonnaise will use olive oil. But there is a perfectly respectable tradition in northern France and elsewhere that employs peanut and other neutrally flavored oils. And its proponents are as committed

Elizabeth David's Everlasting Syllabub

(slightly adapted from *An Omelette and a Glass of Wine,* Viking Press)

- 1 lemon
- 5 ounces white wine or sherry
- 2 tablespoons brandy
- ⅓ cup sugar
- 1¾ cup heavy cream, boiled down to 1⅓ cup and then chilled
- Nutmeg

The day before the syllabub is to be made, put the thinly pared rind of the lemon and the juice in a bowl with the wine and brandy and leave overnight. Next day, strain the wine and lemon mixture into a large and deep bowl. Add the sugar and stir until it has dissolved. Pour in the cream slowly, stirring all the time. Grate in a little nutmeg. Now whisk the mixture until it thickens and will hold a soft peak on the whisk. The process may take 5 minutes, it may take 15. It depends on the cream, the temperature, and the method of whisking . . . .When the cream is ready, spoon it into small glasses, (2 to 2½ ounces) but fill them to overflowing. Once in the glasses, the cream will not spoil nor sink nor separate. As suggested by Sir Kenelm Digby [the seventeenth-century British author], a tiny sprig of rosemary or a little twist of lemon peel can be stuck into each filled glass. Keep the syllabubs in a cool place—not in the refrigerator—until you are ready to serve them. They can be made at least two days before they are needed. The quantities given will fill ten small syllabub or custard cups or sherry glasses and will be enough for four to six people. . . . Remember that in their heyday syllabubs were regarded as refreshments to be offered at card parties, at ball suppers, and at public entertainments, rather than just as a pudding for lunches and dinners, although they did quite often figure as part of the dessert in the days when a choice of sweetmeats, fruits, jellies, confections, and creams was set out in a formal symmetrical array in the center of the table. . . .

Note: In most American homes, since a cool place of the sort commonly available in Britain will be hard to find, it is best to serve this dish shortly after it is made. Refrigeration will solidify the syllabub and change its nature. The reduction of the cream simulates the greater richness of British cream.

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o their practice as those who insist that ruly ideal mayonnaise will avoid vinegar ltogether in favor of lemon juice.

To be fair to her, David is not a purist, ure and simple, and often presents the ase for many versions of the same basic lish. And she goes out of her way to praise ulinary mavericks like Edouard de omiane, whose original contributions to rench food provoked a furor from tradi-ionalists. Indeed, she holds him up as a recursor of the *nouvelle cuisine*: "I won-der how many of the younger of today's professional chefs realize that some of their most publicized inventions were not their's at all, but were derived, however indirectly, from the Polish and Jewish rec-ipes published or described by Pomiane in his books and radio talks of the 1930s. Michel Guerard's *confiture d'oignons,* for instance, surely derived from Pomiane's dish of sweet-sour onions in which the sweetening elements were sultanas and *pain d'epices,* the spiced honey cake of central Europe, and which Pomiane had in turn borrowed from the Jewish cookery of his native Poland."

Without directly saying so, David is acutely aware of the tension in all cooking between the traditional and the new. An-thropologists might call this same opposi-tion a conflict between the synchronic and the diachronic point of view. In plain lan-guage, we can regard mayonnaise as a given, a static artifact existing outside his-tory, whose authentic nature is as un-changing as a primordial totem. Or we can suppose that mayonnaise had and contin-ues to have a history, that its authentic nature is redefined each time you or I whip some up.

Both points of view are, I think, always valid, in cooking as in the rest of life. The synchronic strand is always there, making sense of the diachronic. Our notion of au-thentic mayonnaise underlies our cer-tainty that an egg and oil emulsion aggres-sively flavored with chipotle chilies from Mexico is still a mayonnaise.

This interplay between the previously defined—the authentic—and the newly evolved, makes judgment and taste possi-ble. If we know what mayonnaise has been, we have a baseline for discrimina-tions about the mayonnaise that a chef has just created. These discriminations are difficult. They rest on the elusive idea of authenticity. But without some rough sense of where we have been (the authen-tic), we cannot reasonably embrace the new or reject the bogus.

Raymond Sokolov is a writer whose spe-cial interests are the history and prepara-tion of food.

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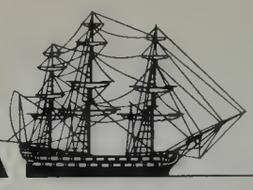

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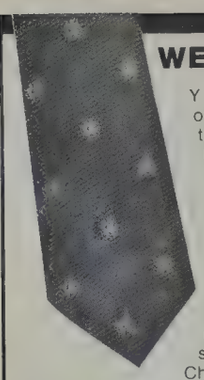

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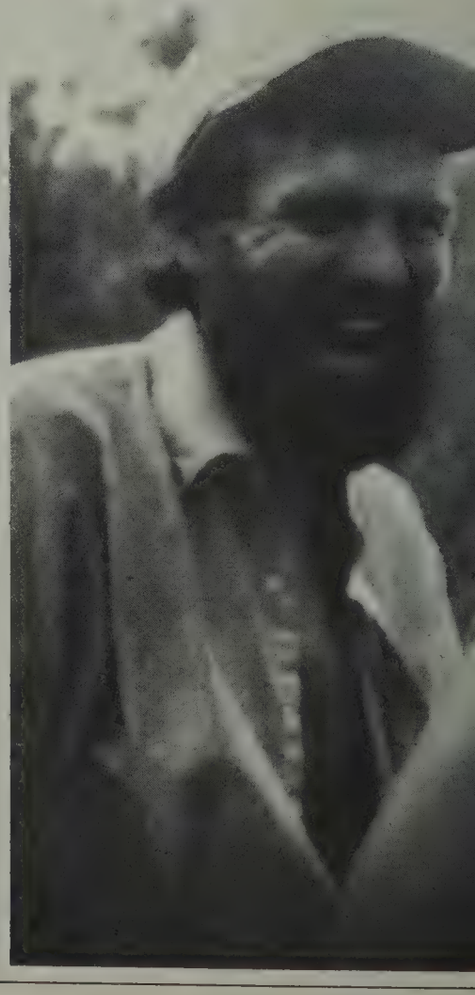
Authors

To reach the white whale study site, naturalist-photographer **Fred Bruemmer** (page 40) flies to Resolute, in the high Arctic, and then hitches a helicopter ride with scientists to the mouth of the Cunningham River. Once there, he shares duties at the research station, including rebuilding the watchtower in the river (it has to be taken down each fall because of ice flows). He even prepares meals, although his cooking abilities are notorious throughout the Arctic. Mostly, he hauls water, washes dishes, and cuts firewood. He also photographs whales, preferably around midnight when the low, reddish sun casts interesting shadows. Bruemmer, who has been studying the white whale for two decades, found his most useful source was *Beluga* (Delphinapterus leucas): *Investigations of the Species,* a 1969 study by Soviet biologist S.E. Kleinenberg and his colleagues. An English version of the 376-page book has been published in Jerusalem by the Israel Program for Scientific Translations.

Born in Colorado, not far from Den ver, **James W. Larrick** (page 56) consid ers himself a natural mountain climbe with an innate curiosity about huma adaptation to high altitudes. He has medical degree and a Ph.D. in mem brane receptor biochemistry from Duk University. Larrick's particular focus i on tribal groups "from both a medica and cultural point of view." Followin that approach, he has done research i Nepal and the Andes as well as in othe locations off the beaten track. "The syn ergy between humans and animals, be tween the Tibetans and their yaks, fo example, illustrates the 'biocultural' ad aptations of the preindustrial popula



ions I have been studying," he says. **Kathy B. Burck**, Larrick's wife and coauthor, is also an M.D. with a Ph.D. in molecular genetics. She shares her husband's research interests in medicine and anthropology and accompanies him on joint field trips.

In addition to the book mentioned in their article, the authors recommend two others for those interested in learning more about life in Tibet: *Going Higher: The Story of Man and Altitude,* by C.S. Houston (Queen City Printers, Inc., Burlington, Vt., 1983); and *Man at High Altitude,* by O. Heath and D.R. Williams (Churchill Livingstone, London, 2d edition, 1981).

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In 1972, while doing fieldwork among the Nahua Indians of Mexico, **Alan R. Sandstrom** (page 66) was startled to observe them cutting paper images of spirits for their rituals, an ancient practice considered obsolete in that particular Indian group. In an attempt to document the Nahua spirit pantheon, Sandstrom (at left) began collecting samples of all the different paper figures, but the task soon reached unmanageable proportions. In his article for *Natural History*, Sandstrom writes of his conclusion that the complex Nahua religion can best be understood as a form of pantheism. The turning point in his thinking came after reading a book on pre-Hispanic Mesoamerican religion, anthropologist Eva Hunt's *The Transformation of the Hummingbird: Cultural Roots of a Zinacantecan Mythical Poem,* published in 1977 by Cornell University Press. A book by Sandstrom and his wife, Pamela Effrein Sandstrom, *Traditional Papermaking and Paper Cult Figures of Mexico,* will be published this spring by Oklahoma University Press. Sandstrom is an associate professor of anthropology at Indiana University–Purdue University at Fort Wayne. His other research among the Nahuas has investigated how their religious and symbol systems support their horticultural practices and, more recently, the cultural change brought about by the discovery of oil in the region where these Indians live. He has also studied the traditional Tibetan medical system and the adaptation of exiled Tibetans to life in northern India.

Seattle-based **Art Wolfe** (page 100) flew to Ellesmere Island last spring to photograph the northern wolves. A professional photographer for eight of his thirty-four years, Wolfe is the author of the recently published *The Imagery of Art Wolfe* (Arpel Graphics), a compendium of nature photographs taken on his travels. The Eureka weather station on Ellesmere, where Wolfe spent four days, may be the northernmost place on the planet where human beings live the year round. He got there by flying to Resolute, near the North Magnetic Pole, on a package tour of the North Pole. "For $8,000, you could do it, too," he says. "You go up there and they give you champagne and crackers for a few hours." From there, Wolfe rode the supply plane to the weather station.

"It was light all day long," he says. "The best shooting time was about 2:30 A.M., when the sun gets as low as it's going to get and there are some nice pinks." He could get within a few feet of the hares at the station because "they were really bold and would hardly move out of the way for the wolves that were scavenging there." But the particular pair in this month's *Natural Moment* were a long way away. Wolfe used an 800-mm lens to photograph them.

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Vol. 95, No. 2, February 1986

American Museum of Natural History, New York, N.Y.
Robert G. Goelet, President
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6 Putting on the Dog *William K. Powers and Marla N. Powers*
Not all Americans follow the taboo against eating dogs.

18 This View of Life *Stephen Jay Gould*
Play It Again, Life

28 A Modern-Day Plague *Jonathan E. Kaplan*
AIDS cases in the United States probably will increase for five more years, at least.

34 A Matter of Taste *Raymond Sokolov*
Cross-Cultural Cooking

40 The Iceman Climbeth *Photographs by John Wright*
Then, it's all downhill to Ecuadorean slurpees.

44 Capuchin Counterpoint *Charles H. Janson*
For some monkeys, cooperative sex has advantages.

54 The Falklands' Johnny Rook *Ian J. Strange*
The fate of this rare bird of prey depends on a precarious web of marine life.

62 Decline and Fall of the Black-Footed Ferret *David Weinberg*
68 On the Track of the Last Black-Footed Ferrets *Louise Richardson*
Will 1986 be the last year on earth for this lovely little mammal?

78 Celestial Events *Thomas D. Nicholson*
Games Planets Play

84 Reviews *Jeremy Bernstein*
Prime Time Science

92 The Living Museum *Marshall Schwartzman*
The Princess of Brazil

98 This Land *Robert H. Mohlenbrock*
Panther Creek Cove, Georgia

102 The Natural Moment *Photograph by Jeff Rotman*
Water Pick

104 Authors

Cover: *An immature black-footed ferret peers out of a prairie dog burrow. Stories on pages 62 and 68. Photograph by Franz J. Camenzind*

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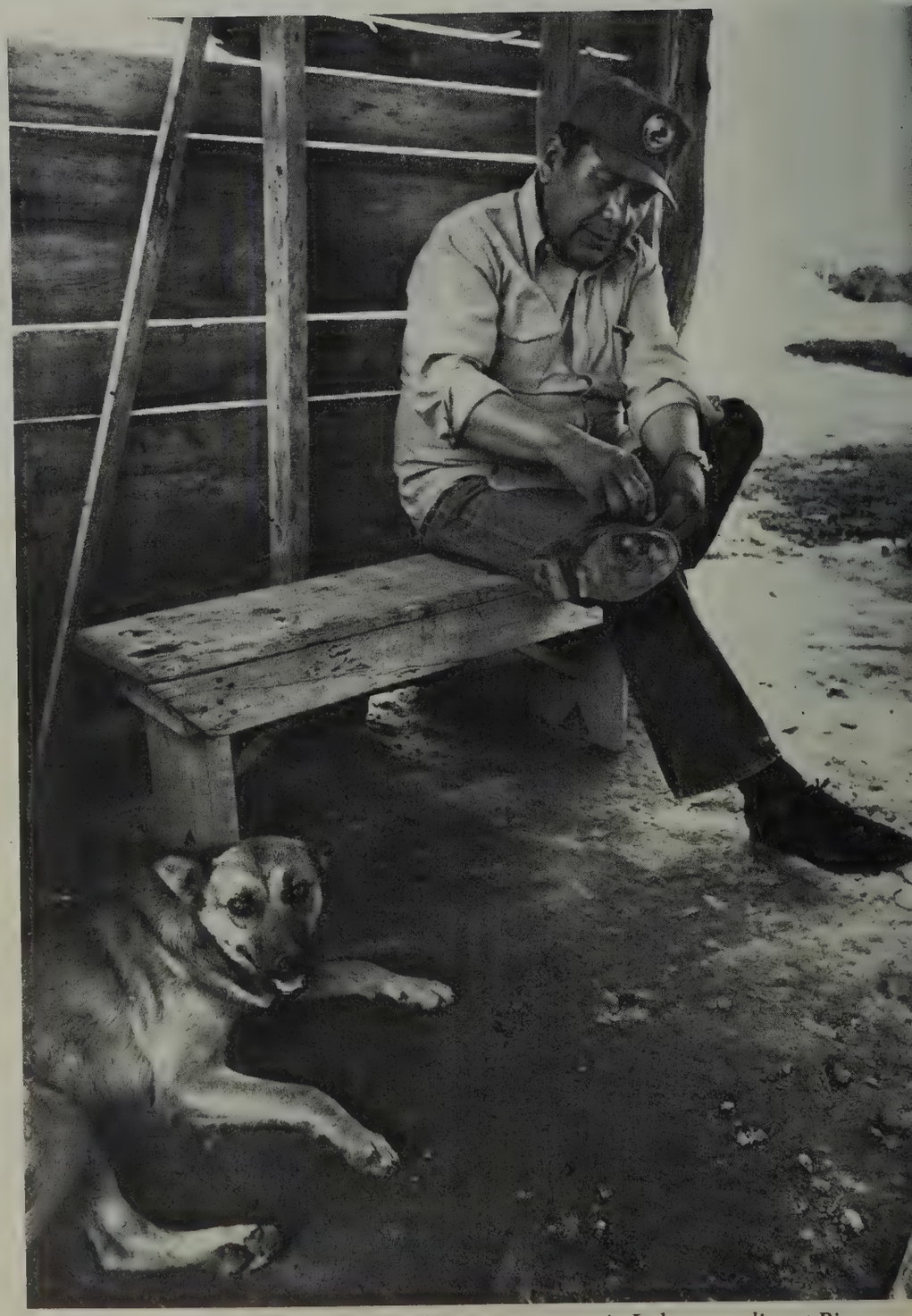
Putting on the Dog

For the Oglala Indians, canine stew is a spiritual delicacy

by William K. Powers and Marla N. Powers

Rev. J. Strzok, S.J



A pet dog sprawls near Leo American Horse, instructor in Lakota studies at Pine Ridge, an Oglala reservation in South Dakota.

Although the dog may be man's best friend, the relationship is not entirely reciprocal. Archeologists and prehistorians tell us that over the past 10,000 years of canine domestication, humans have used the dog as hunter, herder, beast of burden—and source of food, particularly when other food supplies have been scarce. People today generally believe that dogs depend on humans, but during the long period in which humans and dogs evolved their somewhat skewed symbiotic relationship, the opposite was often true. In any case, dogs enjoy a special status as the first animals privileged to share their lives with humans.

In the past, societies have erected shrines to dogs, imitated them, and most of all anthropomorphized them. In mainstream America, dogs have been humanized in a particular way: not only are they part of the family, they are also childlike. People force dependency upon them, look after their health, and safeguard their rights. Societies for the prevention of cruelty to animals seek legislation against their abuse, abandonment, and vivisection. Above all, no matter how much they may be exploited, dogs are not eaten.

Westerners have not always been so sensitive. Early nineteenth-century travelers ate dogs, although not as a delicacy. Explorers Lewis and Clark and painter George Catlin sampled dog stew among the Indians, and writer Francis Parkman reported that both the aroma of a stewing dog and its taste were respectable, although lacking the savor of venison. The flesh of wolf dogs was relished by the employees of the Northwestern and Hudson's Bay companies, who did not generally eat dogs of European descent. But today a taboo against eating dog distinguishes most Americans from the Oglala, a Native American population of 20,000 living on the Pine Ridge Indian

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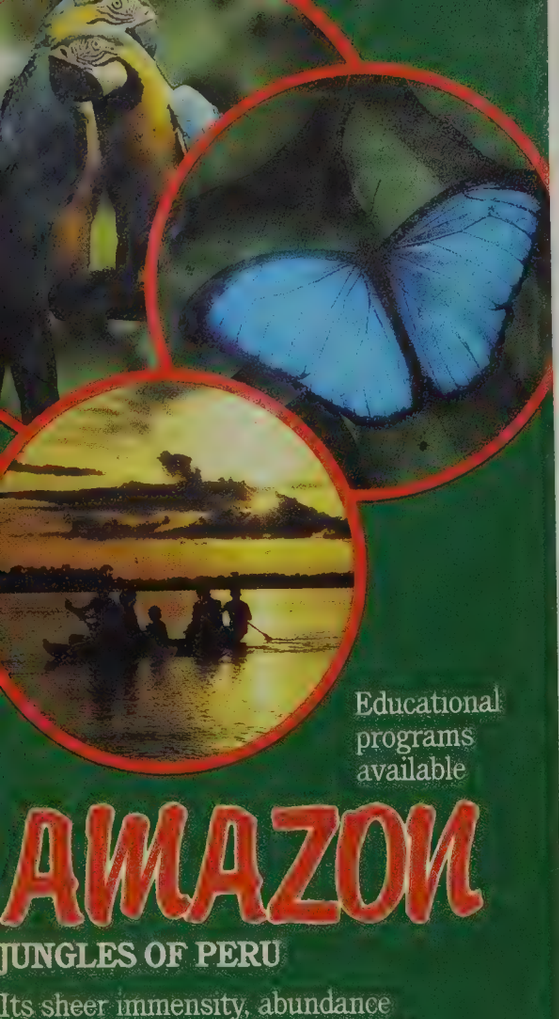

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Oglala women prepare food at Pine Ridge Reservation, South Dakota, ca. 1880.

Reservation in South Dakota (they are one of a number of groups popularly referred to as Sioux). For the Oglala, eating dog is not only a socially permissible culinary practice, but dog stew, its most common form of preparation, is considered a delicacy.

None of the characteristic rituals of the American dog cult are found among the Oglala. Dogs are not brushed, bathed, groomed, clipped, trained, clothed, leashed, or buried in pet cemeteries. The Oglala place no particular value on purebred dogs; the large majority of their canine population is made up of mongrels. In English, the Oglala often refer to their dogs as Indian dogs. Only a few relocated Oglala actually own purebred dogs, which they occasionally bring home to the reservation, much to the amusement of their relations. As in mainstream American culture, dogs are considered to be a kind of human and are imbued with individual personalities, often compared with those of their masters. But Oglala dogs are not thought of as children, they are adults. They spend their lives outdoors, even through the severest winters, and survive exclusively on table scraps and whatever they can scavenge from refuse heaps or steal from their dog neighbors. Children are cautioned to beware of packs of wild, cavorting dogs that roam the towns at night, as if they were humans on a spree.

The average Oglala household owns more dogs than the average non-Indian household, and six to ten are not uncommon. Dogs are considered useful for protecting the house from the incursions of strangers, as well as for announcing the presence of friends. Anyone living on the reservation soon becomes accustomed to dogs barking all night long, and the reason for their nocturnal howling is frequently discussed the next morning, because dogs herald not only the presence of humans but that of ghosts as well. In Lakota, the language of the Oglala, the expression *šungwapa*, "dog barking," is a metaphor for any general commotion. It refers, for example, to the place of a celebration where unattached dogs typically dart from one tent to the next begging for handouts.

Although veterinary medicine has reached the reservation, and a public health program succeeded in eradicating rabies some thirty years ago, dogs are not customarily treated by vets. Mad dogs, mean dogs, and those perceived to be terminally ill with mange or some other illness are simply killed. Even a favorite pet that has lost a momentous battle to an itinerant porcupine and whose snout is irrevocably riddled with quills is not considered worthy of medical attention. Dogs that are losers in nature's battles are removed from the social system: they are most frequently shot and dispatched to the local dump.

Aside from these differences, the Oglala classify dogs much as other Americans do. They recognize the taxonomic relationship between the various members of the family Canidae. The dog (*šunka*) is kin to the wolf (*šunkamanitu tanka* "large wild dog," or *šungmahetu*, "underground dog"), the coyote (*šungmanitu* "wild dog"), and the red fox (*šungila* "reddish dog"). When the Oglala first came in contact with the horse, they considered it a kind of dog, a sacred one (*šunkawakan*). The Oglala name their pet dogs, sometimes with names that reflect an expanding social universe, one inhabited by white men of various sorts. Although many dogs are given Lakota names such as Mato (Bear), Pispiza (Pra

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rie Dog), Šunka (Dog), or Ite Hanska (Long Face), others bear such appellations as Blackie, Butch, Sparky, Crawford, and Mahomet.

For a dog to be given a name means much to its master and even more to the dog, because named dogs are not eaten. Or put the Oglala way, one simply does not name a dog that is likely to become a candidate for the stewpot. This designation is made early in a dog's life, because the preferred eating-dog is a small puppy, between seven and ten weeks of age. An older dog is regarded as too tough and stringy to chew. The person who owns a named or unnamed dog that has managed to survive to give birth to a litter achieves a certain status among Oglalas, for eating-dogs are always in demand for important rituals. Some Oglalas raise dogs for eating purposes, and they treat puppies more like a herd than a litter.

Once a dog is selected, its ritual killing is presided over by a medicine man and two female assistants. The medicine man anoints the puppy with red paint, drawing a line from the tip of the puppy's nose to its tail. The red line is symbolic of the red road, the Oglala equivalent of the straight and narrow, which represents all that is beneficent in the world. The medicine man extols the virtues of the anointed dog, calling it *mitakola,* "my friend," and expresses to those assembled how difficult it is to sacrifice this worthy and faithful creature. He then faces the dog west, while his assistants take their places on the north and south sides of the dog. Each woman places a noose around the dog's neck and secures it snugly. The medicine man, armed with a blunt instrument, stands behind the dog, that is, at its east, and at his signal, the women pull the nooses tightly while the medicine man strikes the dog over the head.

The Oglala liken this manner of killing the dog to its being struck by lightning, and this guarantees that the spirit of the dog will be released and travel to the west, where it will join the Thunder People. The Oglala believe these are the spirits with power over life and death. The Thunder People are themselves symbolized by lightning, underscoring the belief that storms from the west bring with them rains to cleanse Mother Earth.

The medicine man and his assistants delineate sacred space by standing in the place of three of the four winds. The fourth direction, the west, is left open to permit the passing of the dog's spirit. The Oglala believe that the spirit of the dog reaches the west immediately, thus joining the living and the dead. The dog is choked so that it will utter no cry, because the howl of a dog is equated with death. At the same time, since the breath has not left it, the dog is regarded as spiritually alive. The term for breath is *ni*, the same term for life. The dog, then, is regarded as an exemplary messenger of the people, and the dog's spirit carries with it the people's prayers for health and long life for all their relatives.

Once sacrificed, the dog is thrown on an open pit fire to singe off its hair. The two women then wipe off the remaining hair and wash the body in cold water. They then butcher the dog, cutting the flesh of the animal into approximately three-inch

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A Pine Ridge camp on July 4, 1919. The day's celebration included the Kettle Dance.

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squares. These pieces, the liver, and the intact head (which will be given to an important man) are placed in a kettle and boiled in water for several hours. No spices are added. The bones and other innards are burned in the fire.

The skin is left on the meat to insure that the meat remains intact during the cooking; according to the Oglala, this is done so that the total dog may be consumed. When the Oglala feast on common meat, they anticipate that the cooks will prepare more than can be consumed, that the participants will eat beyond satiety, and finally, that they will carry whatever is left to their homes for future consumption. But to feast on dog means that very little will be prepared relative to the number of guests present, that only the oldest men and perhaps the oldest women will be served, and that each will consume only a few morsels. Nothing will be left over. For the Oglala, meat is a gastronomic delicacy, but dog meat is a spiritual one.

As is true of many Oglala institutions, the origin of the dog feast is attributed to a famine. Sometime in the indefinite past, the story goes, Oglala hunters vowed to the Great Spirit that if they could locate food, they would provide a great feast for their dogs. Upon finally discovering a herd of buffalo, the hunters kept their vow, quickly killing the animals, butchering them, and placing the meat in a great pile. They then led their dogs to it, and the dogs devoured it. In myth, human food is consumed by dogs, so that in reality, dogs may be consumed by humans.

Until well into this century, there were three special occasions on which the Oglala consumed dog. One was a feast for prominent men. The second was a ritual of the fraternal society of "clowns" (*Heyoka Kaga*), men who had dreamed of thunder or lightning and were thus required to live out their lives in an antinatural manner—speaking backward, going naked in the winter, and generally inverting normal behavior. The third was the *Yuwipi* ritual, a curing ceremony conducted in a darkened room for a patient suffering from "Indian sickness," any illness believed to have been endemic before European American conquest.

Common to all these occasions was a ritual dance, the Kettle Dance, which was performed before the dog was eaten. They differed in that humans performed the dance in the first two cases, while the spirits of the Thunder People (those to whom the dog is sacrificed) were believed to perform it during the *Yuwipi* ritual.

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Dancers salute the dog in the kettle during a Kettle Dance, July 4, 1919.

With minor variations, the choreography and significance of all three were the same. Today the first two situations do not obtain except in an occasional reenactment of the Kettle Dance, and then normally without using a dog. But the spiritual version—the Kettle Dance as it is performed in the *Yuwipi* ritual—persists.

In the twenty-eight years that we have worked at Pine Ridge and at other reservations, we have witnessed the *Yuwipi* ritual countless times. A medicine man officiates, invoking the spirits of birds, animals, and the Thunder People to join the ordinary humans in the meetinghouse. These spirits are supposed to commune with the medicine man and guide him in curing the patient for whom the meeting has been arranged. The patient may actually be in the room, but frequently the medicine man asks the spirits to visit a patient in a hospital and report back on the patient's condition. While other foods are served at the conclusion of the *Yuwipi*, dog stew is present in the sacred space throughout the meeting.

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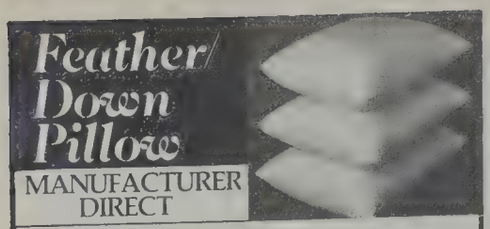

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to be happening, repeating everything the spirits tell him. He reports when the spirits have been coaxed into the meeting (as part of their inducement they are offered dog stew and tobacco) and what instructions in curing procedures they have given him. At this point, he says that the spirits demand the dog stew, and he tells the singers to sing the Kettle Dance songs.

The Thunder People are described as being about three feet tall, daubed with clay, and wearing moccasins and breechcloths. As the first song begins, the Kettle Dance calls for them to salute the kettle by raising first their right hand, then their left, then both hands. Speaking on behalf of the medicine man, the singers intone:

> Great Spirit, pity me;
> I want to live, that is why I do this.

During the second song, the Thunder spirits are described as dancing around the kettle with forked spears, symbolic of lightning, stabbing the choicest morsels of dog stew:

> They stand in place in the sky;
> These, the Thunder People, stand
> in place.

And finally, the spirits are believed to eat, while the singers conclude:

> Over here they are eating dog.
> In the west, the Thunder People
> are eating dog.
> Sacredly, they are eating dog.

According to Oglala belief, the Thunder People are simultaneously performing the ritual in the meetinghouse *and* in their homes in the west with the spirit of the sacrificial puppy. At the conclusion of the Kettle Dance, the medicine man says that the spirits have gone home. The lights are turned on and the people partake of the substance of the dog stew in the same manner that they believe the spirits have partaken of its essence. The people eat, as the Oglala say, not meat, but *pejuta,* "medicine." For them, eating the dog stew is salutory, not nutritional, and the ritual is performed so as to guarantee health and long life. I do this, goes the song, so that I may live.

For the Oglala, the dog is man's best friend because it is man's best sacrifice. It is the animal closest to humans. Like humans, dogs are clever, sagacious, and brave, and they cling dearly to their lives. Like humans, they exist in an unpredictable, profane world and are equally *unšike,* "pitiable." Historically, their lives have been similar to those of humans; they have hunted and gathered precisely the same foods that humans have, from buffalo to table scraps.

Because of the similarity of dogs and humans, Oglalas have sometimes deemed them worthy of imitation. For example, early this century the late Clark Wissler, an anthropologist at the American Museum of Natural History, reported on a fraternal society called the Dogs. Members of the society painted their mouths with a horizontal red band representing the bloody mouth of a feeding coyote. They were said to be particularly good warriors and horse stealers, and during their rituals, they imitated the ferocity of dogs. This was the only fraternal society recorded whose members took names referring to characteristic types of dog behavior and in which a taboo against the eating of dogs was rigorously enforced.

The Dog Society is now defunct, however, and dogs, like some humans, are simply unfortunate beings: they are whipped, beaten, shunned, and starved, yet both people and dogs persist, often against formidable odds. The Oglala recognize and bemoan the diminution of their once proud horse herds and the buffalo's loss of freedom. Even the buffalo herd that roams over the northern part of the reservation is fenced, protected, and controlled. The Oglala fear that the values they once cherished have come to an end because the white man has decreed it.

The white man also disapproves of dog stew. Whites usually do not kill dogs except under humane circumstances, and they certainly do not eat them. In this context, the feast of dog stew, so alien to whites, becomes an act of differentiation for the Oglala. The custom has gained in importance in the past twenty years, as other distinguishing features of Indian culture have been lost. At one time only the elderly ate dog stew, but today men, women, and children of all ages participate freely in the feast.

With the continued pressure on the Oglala to adopt mainstream ways, the ceremoniousness of the dog feast is likely to increase still more. The modern white man eats buffalo, deer, and elk, sometimes even horsemeat. But as long as the white man does not consume dog, he does not consume those who do.

The preceding article is adapted from the authors' article "Metaphysical Aspects of an Oglala Food System," published in Food in the Social Order, *edited by Mary Douglas (New York: Russell Sage, 1984). William K. Powers, who began visiting the Pine Ridge Reservation in 1947 at the age of 13, is professor of anthropology at Rutgers, the State University of New Jersey. His wife and collaborator, Marla N. Powers, is a research associate at the Institute for Research on Women, also at Rutgers.*

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Play It Again, Life

If the great experiment were rerun, the ending might be a world of wiwaxiids or a sea filled with little penis worms

by Stephen Jay Gould

Prediction must be the most difficult of human arts, a source of constant embarrassment for the best-laid guesses of mice and men. My special badge of merit goes to Abraham Lincoln for his unintended taunt to a hundred million schoolchildren forced to memorize the Gettysburg Address: "The world will little note nor long remember what we say here . . . ."

Understanding after the fact confers no special perspicacity. The real test for any diviner can only lie in grasping the outcome at the outset. Correct predictions, in themselves, offer no proof of true wisdom, for how can we distinguish dumb luck from horse sense? The only good experiment is, alas, the most undoable of all intriguing thoughts in a world of irrevocable history—to run back the tape and play it again, Sam.

This famous old thought experiment applies with special fascination to life's history—and for a particular, parochial reason. Humans arrived just yesterday on a stage not noticeably prepared for our advent. Would we appear at all if we could rewind the tape to an appropriate beginning (say the origin of modern phyla in the Cambrian explosion more than 500 million years ago) and simply let it run again? If anything like human intelligence graced the replay, we might feel more secure in a certain sense of inexorability. If the rerun began with trilobites and ended with trilobites, we might treasure our fragility and thank our lucky stars.

Our usual suspicion that we rule by right (and necessity) arises from the common conviction that, however noble the sentiment, the Preacher was no prophet when he proclaimed: "the race is not to the swift, nor the battle to the strong" (Eccles. 9:11). Does not evolution (at least for vertebrates) pass through a sequence of advance from fish to amphibian to reptile to mammal to human? If evolution has moved along such a linear path of progress, how could the story have unfolded in any basically different way? Whatever is, is right. We bolster this dubious interpretation with the cardinal misperception of retrospective history. From a vantage point at the top of the pile, the slopes seem so obviously inclined toward the summit. But again I ask: Can anyone read the final form of a drip castle in the first handful of wet sand?

I believe that the greatest impediment to understanding this thought experiment lies in our lamentable tendency to interpret complex issues as dichotomies with only two possible and contradictory outcomes. In thinking about the rerun of life's tape, we usually entertain two alternatives—either the replay will generate something close to the original story (leading us to argue that life's history makes sense and had to unfold as it did), or the second showing will differ markedly from the first enactment (leading us to conclude that life's history doesn't make much sense and could have ventured down a million other pathways). The history of life, in this dichotomy, is either sensible or random, orderly or chaotic.

I wish to suggest a third, or middle, position. I even believe that I can present some good, if inferential, evidence for it. Suppose that the rerun varies greatly from the original, but that the new version makes perfectly good sense too. Perhaps our world is not random. The race does go to the swift, but each time you play the tape, different lineages win the relay for wondrously diverse reasons. We cannot know who will be swift and why, but winners prevail for good cause. Actual events are accidents in the important sense that any outcome records but one possible result among millions, but each pathway yields to rational interpretation. This third view represents historical contingency in its deep meaning—the enormous complexity and multifarious opportunities that make history quite unpredictable, but sensible after the fact. If we understood contingency in this light, we might steer a proper course between the reefs of strict repetition (to preserve sense) and randomness (to acknowledge the likelihood of different outcomes). Unpredictable does not mean chaotic.

Since our fossil record is largely the story of marine invertebrates (dinosaurs are famous, but rare by contrast), let us consider our current faunas and ask whether a Cambrian observer could have predicted the outcome. Marine animals are amazingly diverse, but clumped at several nodes of overwhelming success. You will find a few aplocophorans, a kinorhynch here and there, and even, if you are lucky (or happen to be hovering over a deep-sea "vent" fauna), a pogonophoran—but the main inhabitants of the ocean floor reside in great abundance within few groups: clams, snails, echinoids, crabs, and polychaete worms. All these creatures do very well, and biologists have demonstrated the functional basis of their success, but could we always have sensed their victory?

As we press the rewind button and watch the tape go back, our obvious stopping point must be the middle Cambrian Burgess Shale, our unique "window" on soft-bodied marine life just after the Cambrian explosion (and subject of my last two columns as well). As we saw last

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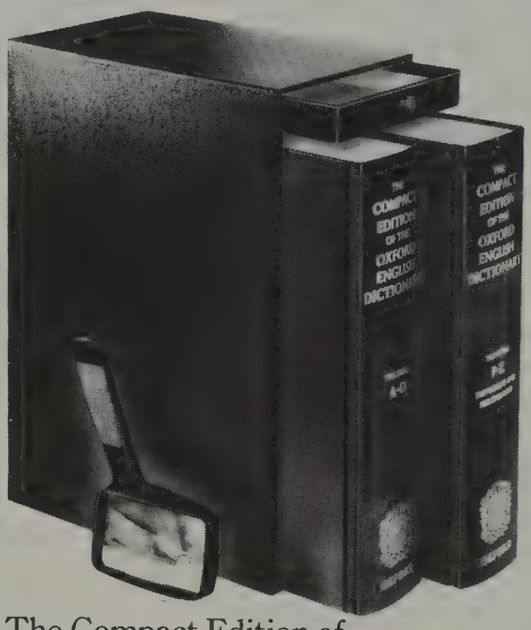

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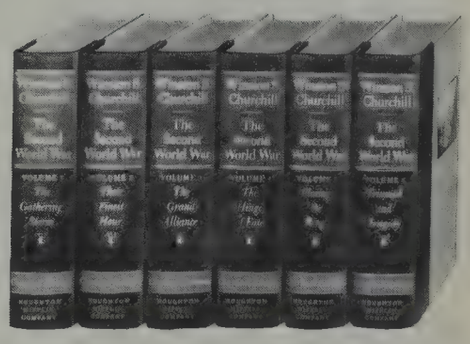

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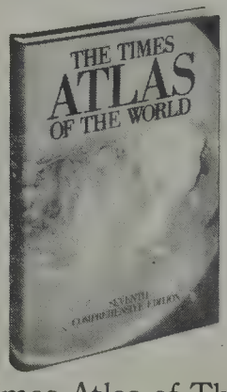

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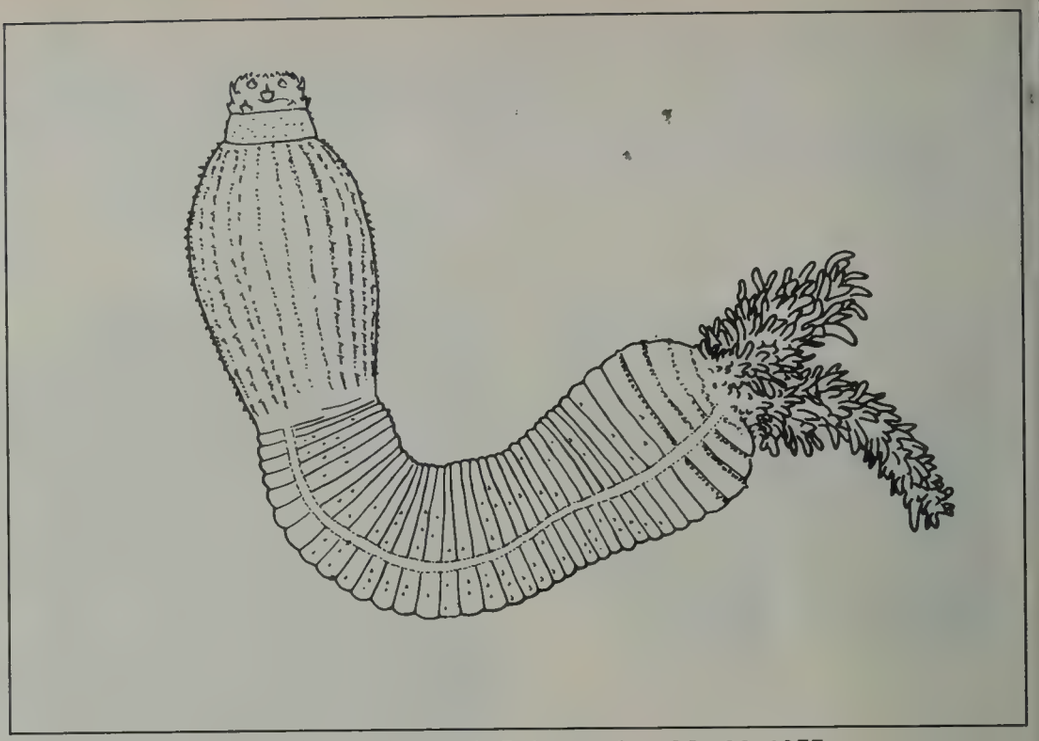

A priapulid worm, from Special Papers in Palaeontology No. 20, *1977*

month, C.D. Walcott, discoverer of this fauna early in our century, shoehorned all its members into modern groups. Since he also tended to force Burgess organisms into well-known (read abundant) classes and phyla, his Burgess bestiary favored groups that still dominate today—and we might grant a kind of stately inevitability to life's tape. But both of my earlier columns also emphasized, as their common theme, the exciting reinterpretation that has recognized a fauna of surpassing strangeness in the Burgess, an assemblage containing a dozen creatures so different from anything living today that we must recognize them as new phyla in our classifications (the highest level of taxonomic distinction below the kingdom Animalia itself).

How does this new interpretation speak to our thought experiment in rewinding life's tape? We might ask two related questions: First, were the unique Burgess phyla doomed by inadequate design to their brief existence as failed experiments in the first flowering of animal life? Second, for living groups with Burgess representatives, would we have known, at this outset, which were destined for domination and which for peripheral status in the nooks and crannies of an unforgiving world? Consider an example of each question—as an illustration for the "might-have-beens" of evolution.

Case 1: The fate of Burgess phyla. The Burgess fauna will reorient the thinking of anyone who suspected that modern animals must have exploited all possible designs because creatures can eat and move in just so many ways. Consider *Opabinia*, with five eyes at the base of a "head" stalk armed with teeth at its front edge; *Anomalocaris* (the "odd shrimp") with one pair of appendages in front, a mouth surrounded by a circlet of plates below, and an expanded wedge-shaped shield, housing the gills, above and behind; or *Hallucigenia* (the name speaks for itself), with seven pairs of fixed spines supporting a trunk with a globular "head" at one end and a spiked "tail" at the other.

Wiwaxia corrugata, the subject of my first Burgess column, lies among the odd-balls. Its simple, wormlike body sported a nearly complete cover of elliptical plates, called sclerites, and two rows of spines along the back. Simon Conway Morris, author of a new monograph on *Wiwaxia* (the initial inspiration for this trilogy of columns), places this animal among the Burgess enigmas but proposes a potentially distant relationship with mollusks. For Conway Morris discovered two bars of teeth, inserted at the front end of the gut and similar in form and position to the distinctive radula of mollusks.

Clams and snails represent one of life's greatest success stories, yet only a few specialists have ever heard of *Wiwaxia.* But who can say that a replay of life's tape would not see the mollusks dive to an early death and wiwaxiids flourish. We know nothing about design or abundance of mollusks and wiwaxiids that would lead our hypothetical Burgess zoologist to specify outcomes without the benefit of hindsight. *Wiwaxia* was not a fragile rarity in Burgess times. Its sclerites fossilized, and we can therefore trace its abundance and distribution beyond the Burgess. Conway

Lenox.

Front view
shown actual size

Morris cites six genera of described Cambrian sclerites that might be wiwaxiids. Mollusks, moreover, had not yet proved their success. We know only two genera of tiny clams for the entire Cambrian, while the larger array of small, twisted, or cap-shaped shells may be snails or monoplacophorans. But we have no definite proof that all are even mollusks.

Conway Morris, after pondering the operation and distribution of wiwaxiids for many years, could not convince himself that any predictable inadequacy had sealed their fate. He wrote:

> In conclusion, if the clock was turned back so metazoan diversification was allowed to rerun across the Precambrian-Cambrian boundary, it seems possible that the successful body plans emerging from this initial burst of evolution may have included wiwaxiids rather than mollusks.

Moreover, the current domination of clams and snails *within* the mollusks seems equally uncertain from a Cambrian perspective. Clams presumably evolved from rostroconchs, an extinct group with an outer covering that seems to include two symmetrical valves (as in clams) but actually grows from a single starting point and then folds over along a pseudohinge. My colleague John Pojeta has just told me that rostroconchs outnumbered clams for the first 100 million years of their coexistence. Our Burgess zoologist might well have placed his money on the ultimate losers.

Case 2: Relative abundances then and now. Consider the current distribution of two phyla sharing the most common of invertebrate body plans—the flexible, elongate, bilateral symmetry of "worms." Polychaetes, the major marine component of the phylum Annelida (including earthworms on land), represent one of life's great success stories. The best modern epitome, Sybil P. Parker's *McGraw-Hill Synopsis and Classification of Living Organisms,* devotes forty pages to a breathless summary of their 87 families, 1,000 genera, and some 8,000 species. Polychaetes range in size from less than one millimeter to more than three meters; they live nearly everywhere, mostly on the sea floor, but some in brackish or fresh water, and a few in moist earth. Their life styles also span the range of the thinkable: most are free living and carnivorous or scavenging, but others dwell commensally with sponges, mollusks, or echinoderms, and some are parasites.

By contrast, consider the priapulids, literally, little penis worms. Priapulids are burrowing worms with bodies divided roughly into three parts: a rear end with one or two appendages; a middle trunk; and a retractable front end, or proboscis. Both the form of the proboscis and its power of erection from the trunk, inevitably reminded early male zoologists of something else to which they were, no doubt, firmly and fondly attached—hence the burden of nomenclature for these creatures as *Priapulus*, or the "little penis."

The armature of the priapulid proboscis might give some cause for alarm in unwarranted analogy. The lower portion sports twenty-five rows of little teeth, or scalids (in most species). An unarmed collar, or buccal ring, surmounts the scalids, while the upper end contains several inscribed pentagons of teeth surrounding the central mouth. Most priapulids are active carnivores, capturing and swallowing their prey whole, although one species may feed on detritus.

But when we turn to Parker's compendium, we find but three pages devoted to priapulids, with a leisurely description of each family. Priapulids just don't contrib-

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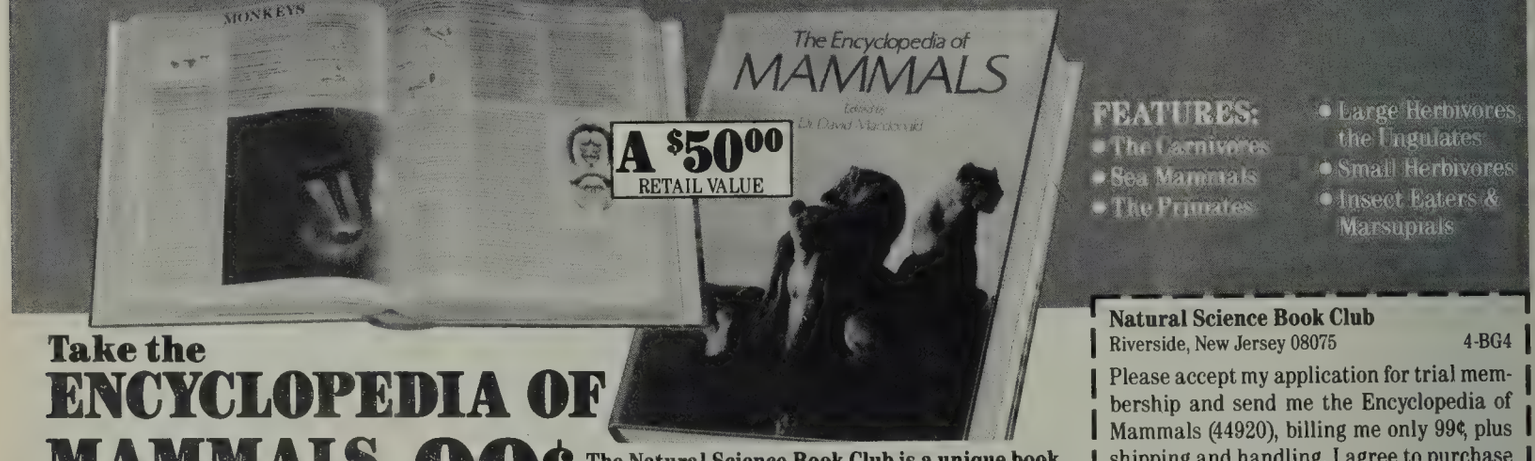

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ute much to an account of organic diversity. Zoologists have found only nine species, allocated to six genera and three families. For some reason, priapulids do not rank among the success stories of modern biology.

An examination of priapulid distribution provides a clue to their relative failure. All priapulids live in unusual, harsh or marginal environments—as if they fail to compete in the shallow, open marine environments frequented by most "standard" organisms of the sea and can hang on only where ordinary creatures don't bother. Two priapulid families (with one species each) include miniaturized worms grown so small that they live among sand grains in the rich and fascinating (but decidedly "unstandard") world of the so-called interstitial fauna. Most priapulids (seven species in four genera) belong to the family Priapulidae, larger worms (up to twenty centimeters) of the macroscopic sea bottom. But these priapulids do not inhabit the richest environments of the shallow water tropics. They live in the coldest realms, at great depths in tropical regions, but rising to shallow waters in the cold climates of high latitudes. They can also tolerate a variety of unusual conditions—low oxygen, hydrogen sulfide poisoning, low salinity, sharp fluctuations in saltiness, and unproductive regions that impose long periods of starvation. It does not strain the boundaries of reasonable inference to argue that priapulids have managed to keep a toehold in a tough world by opting for difficult places devoid of sharp competition.

We might assume that such a striking difference in today's seas recorded something so intrinsic about the relative mettle of these two groups that their geological history should be an uninterrupted tale of polychaete prosperity and priapulid struggle. If so, we are in for yet another surprise from the redoubtable Burgess fauna. This first recorded beginning of modern soft-bodied life contains six genera of polychaetes and six genera of priapulids. (See Simon Conway Morris's monographs on both groups—*Special Papers of the Palaeontological Association of the United Kingdom,* no. 20, 1977, for the priapulids; *Philosophical Transactions of the Royal Society of London,* vol. 285, 1979, for the polychaetes.)

This difference between past and present extends well beyond this bald numerical statement, impressive enough in itself. The Burgess priapulids are, numerically, a major component of the fauna and, perhaps, the earth's first important soft-bodied carnivores. *Ottoia prolifica,* most common of the Burgess priapulids, swallowed its prey whole. Hyolithids (conical shelled creatures of uncertain affinity) were favored as food. Thirty-one specimens have been found in the guts of *Ottoia,* most swallowed in the same orientation (and, therefore, almost certainly hunted and consumed in a definite style). One *Ottoia* had six hyolithids in its gut. Another specimen had eaten one of its own—the first recorded example of cannibalism in our fossil record.

Polychaetes, by contrast, are much rarer numerically, if equal to priapulids in taxonomic diversity (and range of exploited environments, with active swimmers, burrowers, and sediment eaters among the polychaetes). Simon Conway Morris remarks: "In comparison with the situation in many modern marine environments, the Burgess Shale polychaetes had a relatively minor role."

Obviously, something dramatic (and disastrous) has happened to priapulids since the Burgess. Once they had no rivals for abundance among soft-bodied forms, exceeding even the proud polychaetes of current majesty. Now they are few and forgotten, denizens of the ocean's spatial and environmental peripheries. The entire modern world contains no more genera of priapulids than the single Burgess fauna from one quarry in British Columbia—

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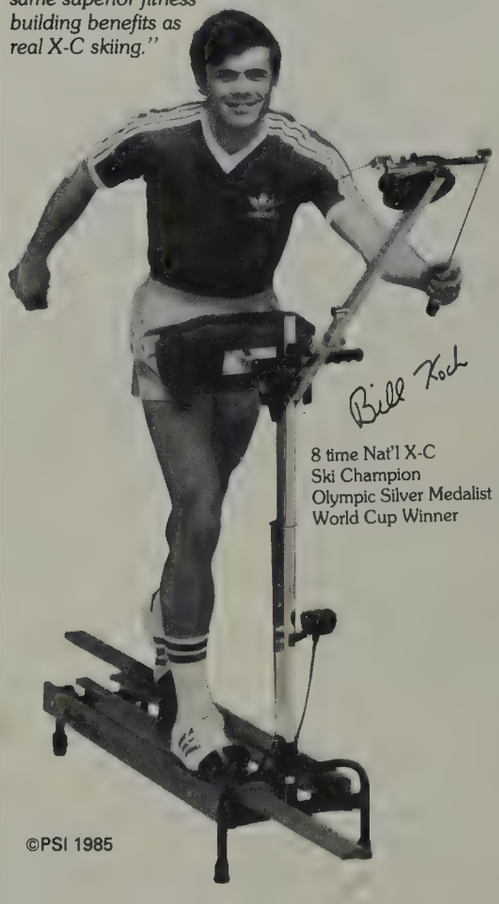

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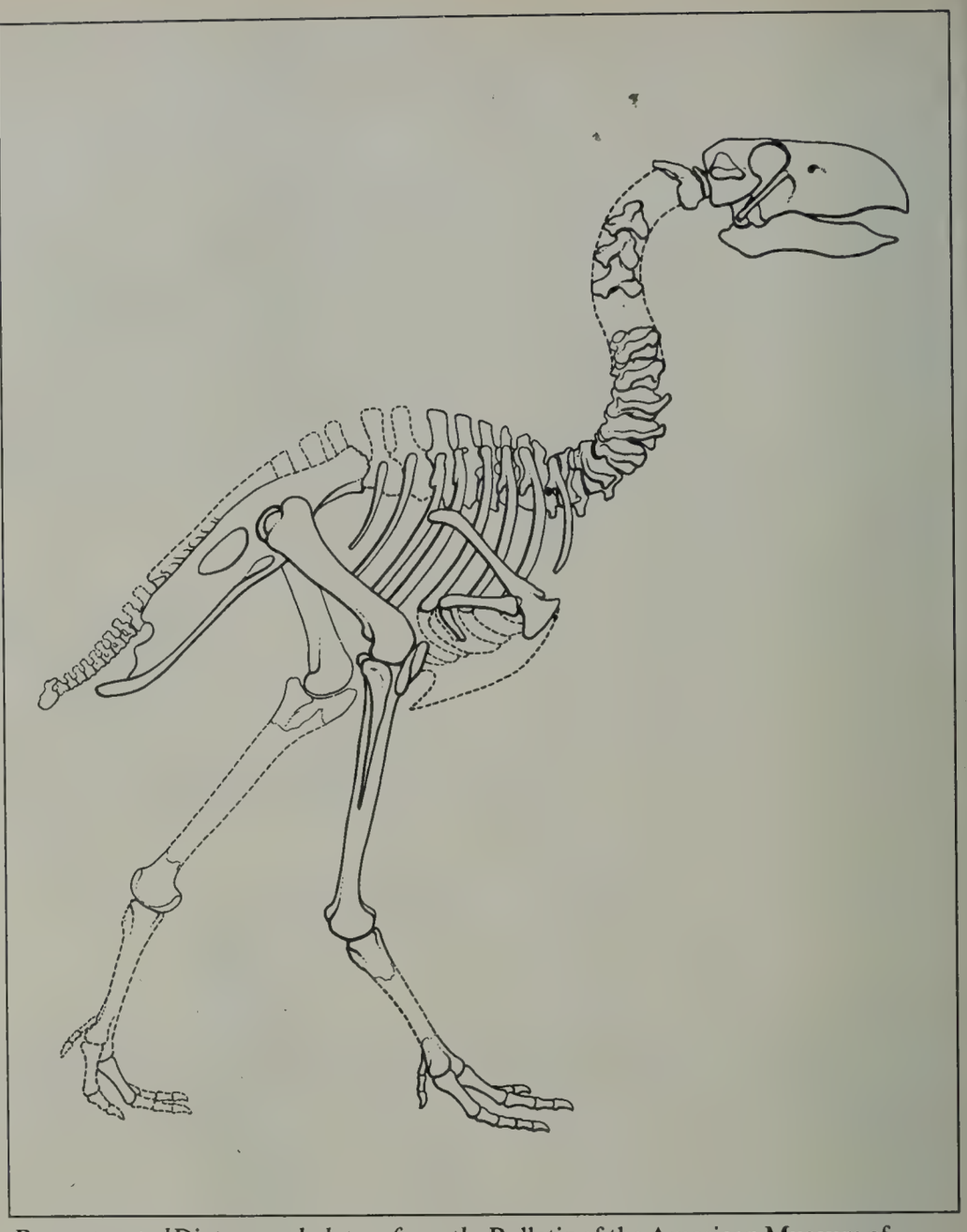

Reconstructed Diatryma *skeleton, from the* Bulletin of the American Museum of Natural History, *1917*

while Burgess priapulids occupied center stage, not the tawdry provinces. What happened?

We do not know. It is tempting to argue that polychaetes had some obvious biological leverage from the start and were destined for domination, however modest their beginning. But we have no idea what such an advantage might be. Conway Morris makes the intriguing observation that Burgess polychaetes had no jaws and that these organs of successful polychaete predators did not evolve until the subsequent Ordovician period. Perhaps the origin of jaws was what gave polychaetes their edge over the previously more abundant priapulids.

This tale is plausible and may be true but we do not know, and a correlation (jaws with the beginning of dominance) need not imply a cause. In any case, our hypothetical Burgess geologist would not have known that the modest polychaetes would evolve jaws fifty million years hence.

The distribution of modern priapulids does indicate a basic failure relative to Burgess abundances, but who knows the whys or wherefores? And who can say that a rerun of life's tape would not yield a modern world dominated by priapulids, with a few struggling jawless polychaetes at a tenuous periphery. What did happen makes sense: our world is not chaotic. But many other plausible scenarios would have satisfied any modern votary of progress and good sense, and priapulid dominance lies firmly among the might-have-beens.

Are these Burgess fancies a common property of life's history throughout or an oddity of uncertain beginnings superseded by later inexorability? Consider one more might-have-been: When dinosaurs perished in the Cretaceous debacle, they left a vacuum in the world of large-bodied

carnivores. Did the current reign of cats and dogs emerge by predictable necessity or contingent fortune? Would an Eocene paleontologist, surveying the vertebrate world fifty million years ago, have singled out for success the ancestors of Leo, king of beasts?

I doubt it. The Eocene world sported many lineages of mammalian carnivores, only one ancestral to modern forms and not especially distinguished at the time. But the Eocene featured a special moment in the history of carnivores, a pivot between two possibilities: one realized; the other forgotten. Mammals did not hold all the chips. In 1917, the American paleontologists W.D. Matthew and W. Granger described in the *Bulletin of the American Museum of Natural History* the skeleton of a giant predacious bird from the Eocene of Wyoming, *Diatryma gigantea.* They wrote of "this magnificent and quite unexpected bird skeleton":

Diatryma was a gigantic bird, ground living and with vestigial wings. In bulk of body and limbs it equalled all but the largest of the moas and surpassed any living bird .... The height of the reconstructed skeleton is nearly 7 feet. The neck and head were totally unlike any living bird, the neck short and very massive, the head of enormous size with a huge compressed beak.

The gigantic head and short, powerful neck identified *Diatryma* as a fierce carnivore, in sharp contrast with the small heads and long slender necks of more peaceful ratites (ostriches, rheas, and their relatives). Like *Tyrannosaurus* with its diminutive forelimbs, but massive head and powerful hindlimbs, *Diatryma* must have kicked, clawed, and bitten its prey into submission.

Diatrymids, distant relatives perhaps of cranes but no kin to ostriches and their ilk, ranged over Europe and North America for several million years. The plum of dominant carnivory could have fallen to the birds, but mammals finally prevailed, and we do not know why. We can invent stories about two legs, bird brains, and no teeth as necessarily inferior to all fours and sharp canines, but we know in our heart of hearts that if birds had won, we could tell just as good a tale about their inevitable success. A.S. Romer, leading vertebrate paleontologist of a generation just past, wrote in his textbook, the bible of the profession:

The presence of this great bird at a time when mammals were, for the most part, of very small size (the contemporary horse was the size of a fox terrier) suggests some interesting possibilities—which never materialized. The great reptiles had died off, and the surface of the earth was open for

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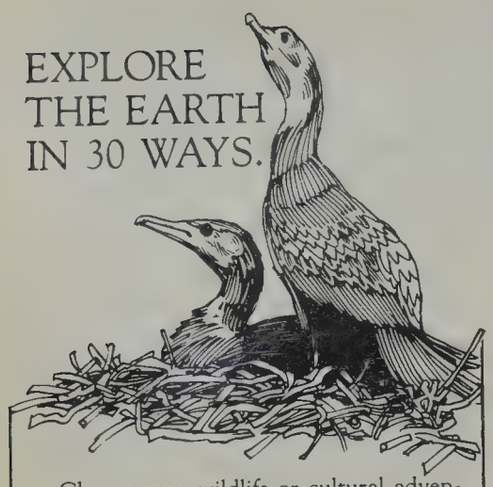

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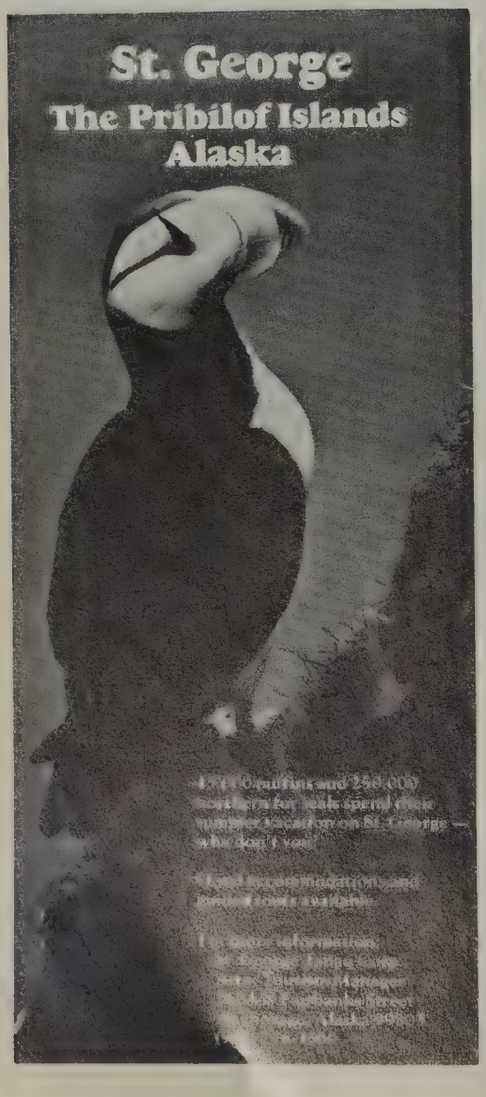

conquest. As possible successors there were the mammals and the birds. The former succeeded in the conquest, but the appearance of such a form as *Diatryma* shows that the birds were, at the beginning, rivals of the mammals.

In all these speculations about rerunning life's tape, we lament our lack of any controlled experiment. We cannot instigate the actual replay, and our planet provided only one run-through. Wiwaxiids are gone forever, and priapulids fell on a global scale. But the crucial Eocene pivot between birds and mammals provides more and different evidence. For once, our recalcitrant and complex planet actually performed a proper experiment for us. This particular tape did have a rerun in South America—and this time the birds won or at least held mammals to a respectable draw!

South America was an island continent, a kind of super-Australia, until the Isthmus of Panama rose just a few million years ago. Most animals usually considered as distinctively South American—jaguars, llamas, and tapirs, for example—are North American migrants of postisthmian arrival. The great native fauna of South America is largely gone (or surviving as a poor, if fascinating, remnant of armadillos, sloths and the "Virginia" opossum, among others). No placental carnivores inhabited this giant ark. Most popular books tell us that the native South American carnivores were all marsupials, the so-called borhyaenids. They neglect to say that another prominent group—the phororhacids, or giant ground birds—fared just as well if not better. Phororhacids also sported large heads and short, stout necks, but they were not closely related to *Diatryma*. Birds had a second and separate try as dominant carnivores in South America, and this time they won.

From the smug outlook of our placental-centered parochialism, we may say that birds could triumph in South America only because marsupials are inferior to placentals and did not offer the kind of challenge that conquered predacious ground birds in Europe and North America. But can we be so sure? Borhyaenids could also be large and fierce, ranging to bear size and including such formidable creatures as *Thylacosmilus,* the marsupial sabertooth. We might also sneer and point out that, in any case, phororhacids quickly snuffed it (along with borhyaenids) as soon as superior placentals flooded over the rising isthmus. But this common saga of progress will not wash either. As G.G. Simpson, our greatest expert on the evolution of South American mammals, wrote in one of his last books (*Splendid Isolation,* Yale University Press, 1980):

> It has sometimes been said that these and other flightless South American birds . . . survived because there were long no placental carnivores on that continent. That speculation is far from convincing . . . . Most of the phororhacids became extinct before, only a straggler or two after, placental carnivores reached South America. Many of the borhyaenids that lived among these birds for many millions of years were highly predacious . . . . The phorochacids . . . were more likely to kill than to be killed by mammals.

We must conclude, I think, that South America does represent a legitimate replay, round two for the birds.

One may properly ask, in conclusion, if all these reveries really make any difference. Who cares, in the old spirit of America at its pragmatic best? It is fun to imagine oneself as a sort of divine disk jockey, sitting before the tape machine of time with a library of cassettes labeled priapulids, pogonophorans, polychaetes, and primates. But would it really matter if all the reruns discussed in this essay produced their unrealized opposite—and we inhabited a world of wiwaxiids, a sea floor littered with little penis worms, and forests full of phororhacids. We might be shucking sclerites instead of opening shells in preparing our clambakes. Our trophy rooms might vie for the longest *Diatryma* beak, not the richest lion mane. But what would be fundamentally different?

Everything, I suggest. Our literary metaphors have correctly captured the theme of contingency—from the old saw about kingdoms lost for want of a horseshoe nail, to Marty McFly struggling to unite his prospective parents in *Back To The Future.* The divine tape player holds a million scenarios, each perfectly sensible. Little quirks at the outset, chosen for no particular reason, unleash cascades of consequences that make a particular future seem inevitable in retrospect. But the slightest early nudge contacts a different groove, and history veers into another plausible channel, diverging continually from its original pathway. The end results are so different, the initial perturbation so apparently trivial. If little penis worms ruled the sea, I have no confidence that *Australopithecus* would ever have walked erect on the savannas of Africa. For ourselves, we can only exclaim: O brave—and improbable—new world, that has such people in it.

Stephen Jay Gould teaches biology, geology, and the history of science at Harvard University.

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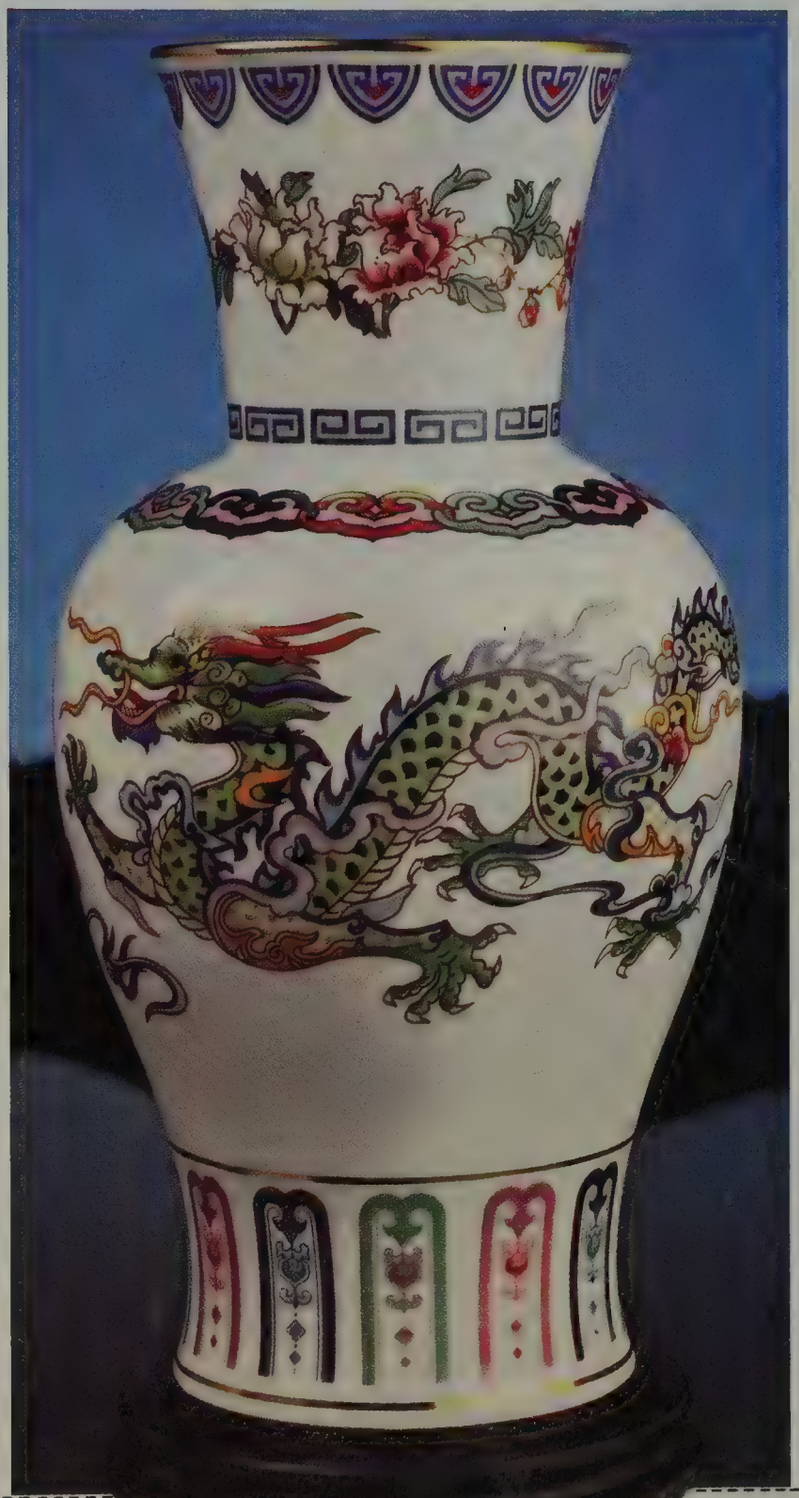

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A Modern-Day Plague

The AIDS virus has found a niche in our society, and it acts as if it wants to stay

by Jonathan E. Kaplan

A generation has grown up since the last lethal communicable disease swept through the United States. To those under thirty, AIDS must seem a wholly new phenomenon, but epidemics have always been with us. In our early history, smallpox decimated Indian populations, and in colonial times, yellow fever and cholera periodically wreaked havoc in the cities. Influenza killed 500,000 in the United States in the winter of 1918/19; and in the early 1950s, polio increased at an alarming rate before the Salk vaccine effectively halted the epidemic at mid-decade. Other infectious diseases have played important roles in world history: typhus determined the outcomes of military campaigns; plague killed one-fourth of the population of Europe in the late fourteenth century.

Acquired immunodeficiency syndrome (AIDS), the devastating illness caused by human T-lymphotropic virus type III, has already proved itself a formidable member of this elite group of epidemic diseases. AIDS destroys the immune system and renders the victim susceptible to a variety of unusual infections and tumors. First recognized in 1981 by astute physicians in Los Angeles and New York, cases of AIDS in the United States have increased exponentially. One thousand cases had been diagnosed by early 1984, and 10,000 in early 1985. As many as 25,000 cases will probably be recognized before this summer begins. AIDS eventually kills nearly all of its victims; at least 75 percent of patients diagnosed before January 1983 have died. As many as one million others in the United States have been infected with the AIDS virus but few have any symptoms of the disease. About 5 percent of this already infected group (another 50,000 people) will be counted among the "new" cases of AIDS within the next few years.

Although epidemics frequently hit some elements of the population more than others, AIDS has the unique feature of targeting very specific minority groups. From the beginning, homosexual men were recognized as being at highest risk, and they still account for 73 percent of adult cases reported to the Centers for Disease Control in Atlanta. Intravenous drug users account for almost all the rest (17 percent), with the remainder being found among hemophiliacs, recipients of blood transfusions, heterosexual partners of persons in high-risk groups, children born to mothers infected before or during pregnancy, and emigrants from countries where the infection is prevalent.

How hard AIDS has hit homosexuals can be appreciated by comparing its incidence rates nationally (usually expressed as new cases per 100,000 people per year) with those of polio and chicken pox in another subgroup of the population: children. In 1952, at the peak of the polio epidemic, for instance, the incidence of that paralytic disease among children under fifteen was about 32 per 100,000. Two years ago, the incidence of chicken pox among five- to nine-year-old children was 172 per 100,000. Among never-married males fifteen years and older (the demographic group within which most homosexual males are presumed to be included), the 1984 AIDS incidence rate was 14.3, about half that of polio in children at the epidemic's peak. In never-married men in Manhattan, however, the AIDS rate was 263.2; and in San Francisco, 339.8. In other words, AIDS has been cropping up among never-married

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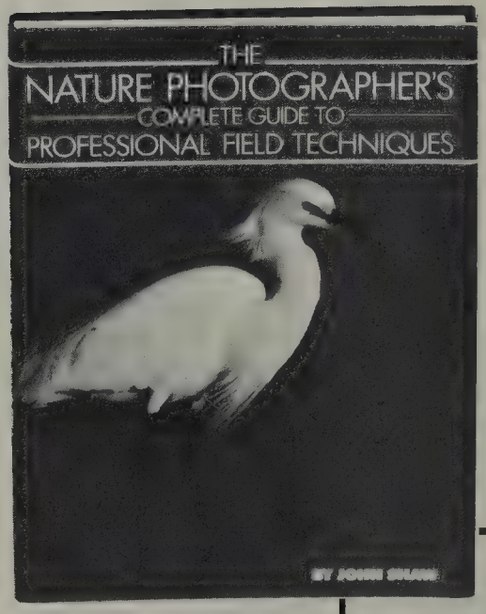

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men in San Francisco at twice the rate that chicken pox hits young children in the United States. Incidence per 100,000 is also alarmingly high among intravenous drug users (167.7 in the United States, 261.1 in New York City, and 350.0 in New Jersey), Haitians who entered the United States after 1977 (101.0), and persons with hemophilia type A (345.7).

An even greater appreciation of the impact of the AIDS epidemic can be had by looking at death rates. AIDS is a fatal disease, but the death rate lags behind the incidence rate because of the time it takes for the disease to run its course. The national death rate for AIDS in 1984 was about 0.5 deaths per 100,000—at first glance not too frightening a figure compared with the ten leading causes of death in the United States, which range from heart disease (335 per 100,000) to suicide (12 per 100,000). However, among males aged thirty to thirty-nine in New York City, the death rate for AIDS in 1984 was 88 per 100,000, higher than the rates for homicide and liver disease, the second and third ranking causes of death. When one considers the average age of the AIDS victims (thirty-six) and their expected life span (sixty-five), the number of years of potential life lost in this group is disturbingly high. In fact, among single men aged twenty-five to forty-four in the United States, AIDS is the fourth leading cause of potential years lost. In Manhattan and San Francisco, it ranks first.

The high rates of AIDS in these risk groups can be readily explained by the established routes of transmission of the AIDS virus—blood or blood products (intravenous drug users who use contaminated needles, hemophiliacs, and recipients of blood transfusions) and sexual contact (gay men, heterosexual contacts of persons in high-risk groups, and persons from countries in which the disease is highly prevalent).

How is it, in this age of advanced technology, antibiotics, and vaccines, that the AIDS virus has gained such a stronghold in our society and specifically in these high-risk groups? The answer lies in some special properties of the virus that set it apart from other epidemic-causing agents in history. First, the virus appears extraordinarily well adapted to human blood lymphocytes, specifically to a subpopulation of these cells called T-helper cells, which serve as orchestrators of the immune system. In a small number of those infected to date with the virus—about 15,000—the virus has produced sufficient damage to the T-helper cells to result in the condition we call AIDS. But in the vast majority of the million or so persons infected in the United States—perhaps 80 percent—the virus, for reasons that are not understood, leaves the host free of symptoms. A few of these persons—perhaps 5 percent—will develop AIDS in the next few years, but most will probably never become ill. Most important in terms of the future of the epidemic is that these asymptomatic persons will continue to harbor the virus in their blood for years, possibly for life. The immune system manufactures antibodies against the virus, which can now be measured in a blood test, but these antibodies do not appear capable of removing the virus from the blood. Our current interpretation of a positive antibody test is that it indicates the presence of a current AIDS-virus infection. Persons who test positive provide a sanctuary for the virus but may not be aware of their infection. Many, if not all of them, are capable of transmitting the virus to others through contact with blood or contaminated needles, through sexual contact, or to children during pregnancy or at the time of birth.

Another property of the AIDS virus is that it does not appear to be confined to blood lymphocytes. Recent studies of AIDS patients with neurological conditions, such as dementia, have shown that the virus finds its way into the brain. This finding is extremely ominous from a therapeutic point of view because brain tissue is separated from the bloodstream by a physiologic-anatomic obstacle called the blood brain barrier, which some antiviral drugs cannot penetrate. When and if an effective antiviral compound is discovered (and we have a very poor track record of finding such drugs, as opposed to antibacterial compounds), the presence of the AIDS virus in the brain may pose a difficult stumbling block to its eradication.

Finally, the AIDS virus has already given notice that it does not lend itself easily to the creation of a vaccine. In vaccines, components of infectious organisms, called antigens, are used to stimulate production of antibodies by the immune system. The AIDS viruses that have been isolated to date show substantial variation in their genetic composition. Since the genetic material directs the production of virus antigens, it follows that the AIDS

ERRATUM: In "A Tree of Life Grows in Brazil" (December 1985), two photo credits were transposed. The photograph of an Apinaje woman peeling babassu fruit, page 44, was taken by Michael J. Balick; the one on the far right of page 45 should have been credited to Randall Hyman.

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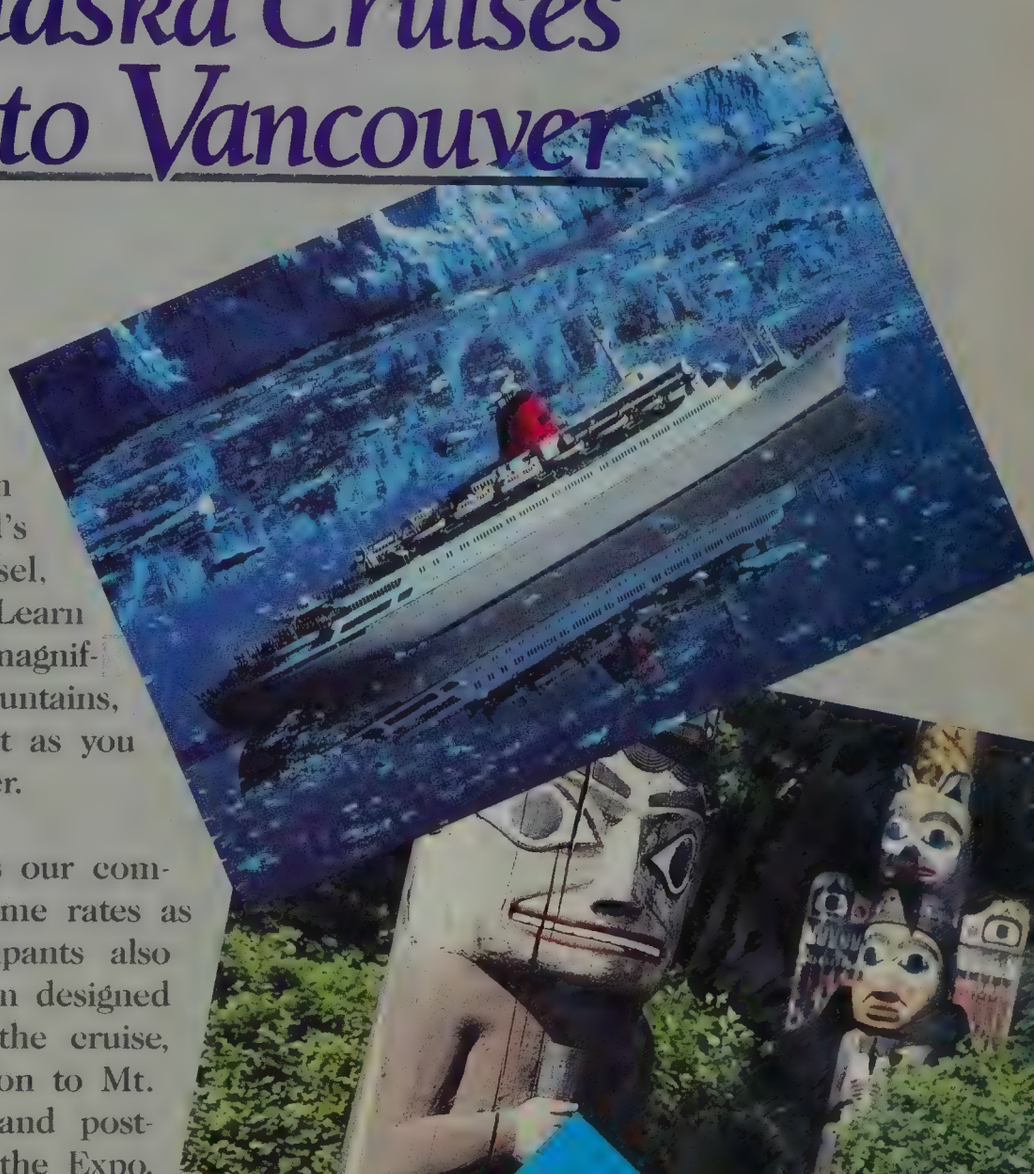

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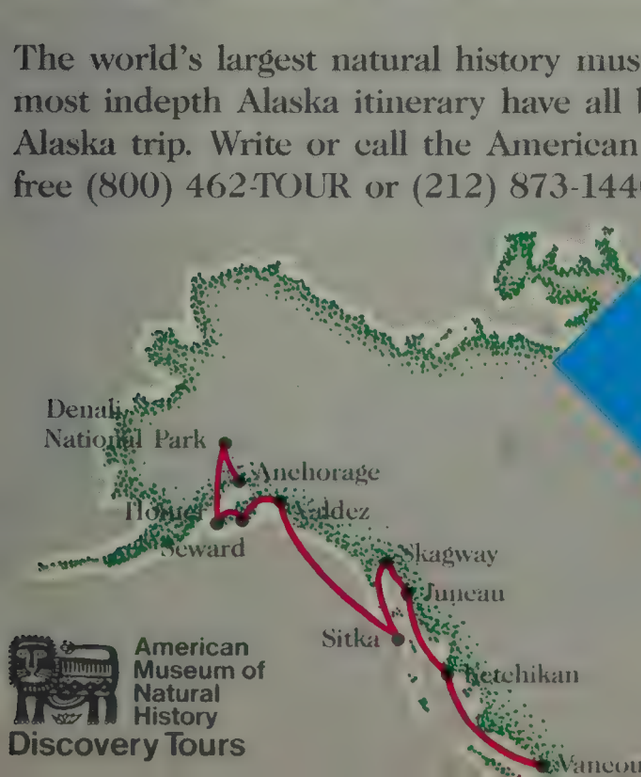

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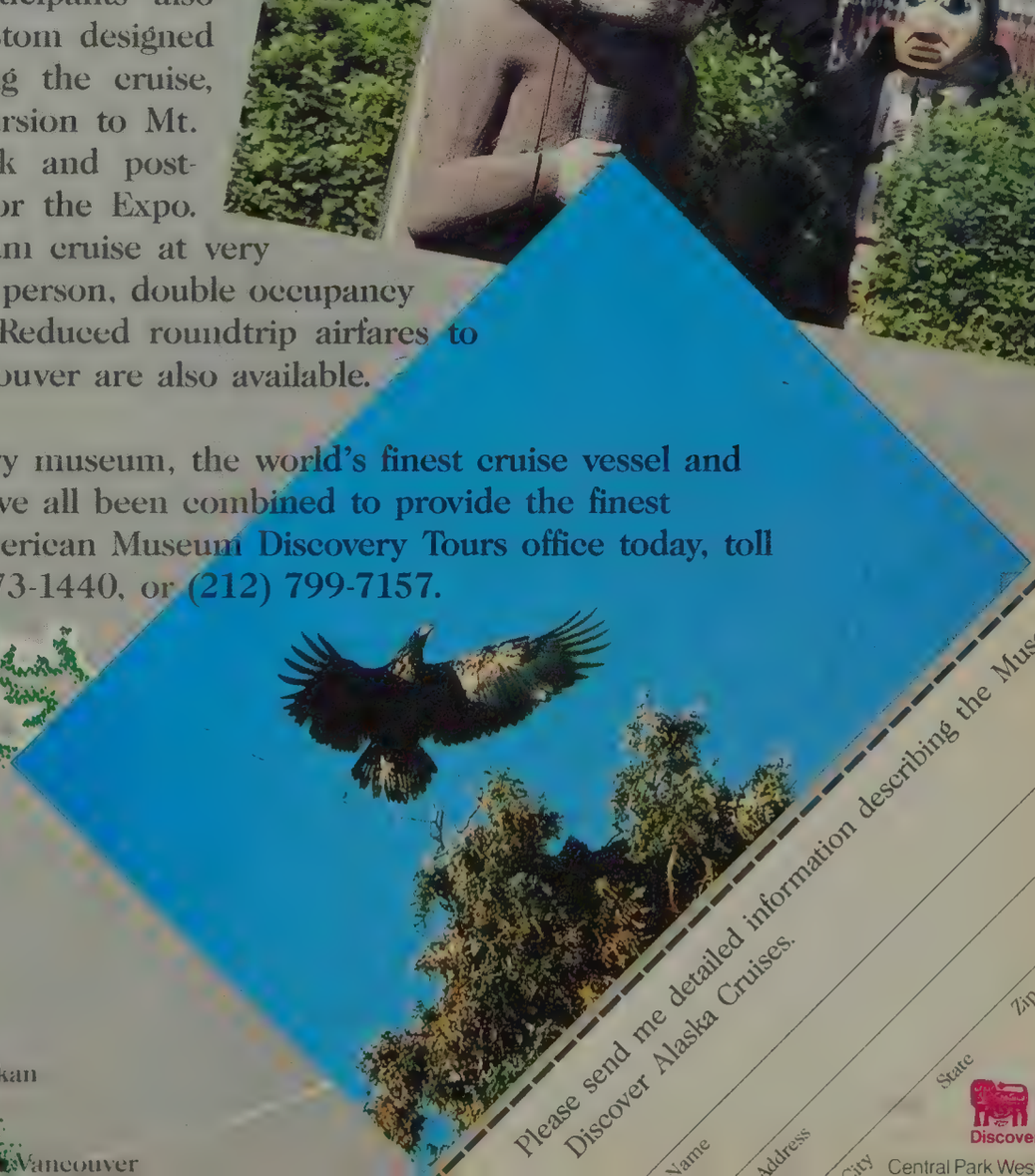

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virus might prove to have many important antigens and that many vaccines will be required to include them all. Researchers are currently seeking an antigen common to all strains that might be suitable for use in a vaccine, but the process of discovering such an antigen, creating a vaccine that will stimulate production of antibodies that will neutralize the virus, and testing the vaccine may take years, if it can be accomplished at all.

The AIDS virus has several built-in mechanisms of survival, both in the individual and in the community-at-large, that are quite unlike any of its epidemic predecessors. Influenza virus, for example, persists in human beings for only a few days and stimulates antibodies that protect the patient from subsequent infection. Once the supply of susceptible individuals in the population is exhausted, the virus either disappears or finds refuge in such animals as pigs, horses, and birds. The epidemic of 1918/19 was over by the spring of 1919. Yellow fever virus is dependent on a mosquito—*Aedes aegypti*—for transmission to humans, and infection is short-lived. Environmental conditions become unsuitable for the survival of the mosquito in the fall in temperate climates, and epidemics in colonial America waned in September and October. Smallpox, like influenza, may quickly exhaust a susceptible population. But this virus (unlike influenza) has the additional disadvantage of having nowhere in nature to reside once humans are no longer available. This feature of its epidemiology allowed the possibility of quarantine of patients and interruption of transmission, which, coupled with vaccination, led to eradication of this disease in 1980. Polio and measles are other examples in which vaccination has led to epidemic control.

What can we expect from AIDS in the next five to ten years? Will the incidence continue to rise in the high-risk groups? Will other population groups experience high incidence rates? The answers to these questions will depend on how we intervene to prevent transmission of the virus, since it is abundantly clear that the virus enjoys its stable relationship with man and will not disappear on its own. We have already witnessed the development of methods to prevent transmission through blood and blood products by heat treatment of clotting-factor concentrates used to treat hemophiliacs (simply heating at 56° C for ten minutes destroys the AIDS virus), and screening tests for blood donors, which have rendered safe the nation's blood supply. Several antiviral compounds that might be used to treat patients who already have AIDS or who are otherwise infected with HTLV-III are being tested, but it is doubtful that any will prove effective and become available for at least five years. Similarly, for reasons already discussed, an AIDS vaccine to prevent the initial infection is probably years away. Since sexual transmission of the virus is the primary mode of spread and will be so for years to come, we must resort to prevention—a change in sexual behavior—if we are to contain the epidemic.

The gay population has demonstrated that such change in sexual behavior is possible. Recent studies in San Francisco indicated a substantial decrease in number of sexual partners between 1984 and 1985, and a decrease in specific high-risk sexual practices. Unfortunately, in San Francisco it is probably too late. As many as 75 percent of gay men in this city may already be infected. Thus, even a substantial reduction in number of sexual partners per year may be ineffective in reducing the spread of the virus since the probability that any given partner will be infected has increased dramatically.

A question of great concern to hetero-

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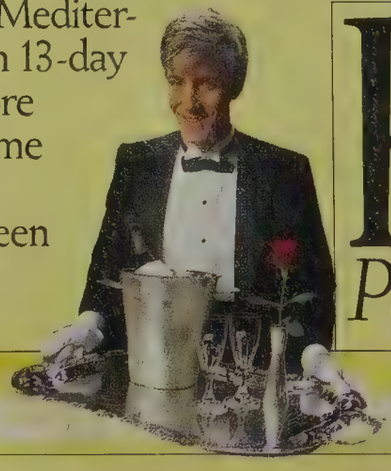

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sexuals in the United States is how the disease will spread in the "general population" (a somewhat unfortunate term, since no minority group merits exclusion from the general population). At present, the prevalence of the virus in the U.S. population, as determined by blood donors (persons in high-risk groups are asked to exclude themselves), is only a fraction of one percent. Thus, there is a low probability of acquiring the infection sexually from one who is not a member of a high-risk group. It is also clear that "promiscuous" individuals (here defined as anyone with more than one sexual partner) are pressing their luck. For one does not always know whether one's sexual partner is a member of a high-risk group or whether he or she has been a sexual partner of a person in a high-risk group. The question is, Will heterosexuals heed the warning provided by the gay population and modify their sexual behavior before the prevalence of infection increases to levels where such modification will no longer be effective?

AIDS in the United States will probably increase for at least five years and perhaps longer owing to the appearance of the disease in those already infected and to continued transmission (primarily sexual, but also among intravenous drug users and from infected mother to child). Incidence will also rise among promiscuous heterosexuals through inadvertent exposures. In other words, AIDS will be contracted by men who have been sexual partners of female drug abusers or prostitutes, and by women who have had sexual relations with intravenous drug abusers or men whom they did not know to be bisexual. Incidence in this group will not rise as dramatically as it has among gays, however, because heterosexuals tend to have fewer sexual partners than homosexual men and because some modification of sexual behavior may occur before the prevalence of infection in this group rises too high.

In his celebrated novel *The Plague,* Albert Camus wrote, "There have been as many plagues as wars in history; yet always plagues and wars take people equally by surprise." The AIDS virus indeed took us by surprise, and it has thus far enjoyed an advantage in its relationship with the human organism. It remains to be seen how we, collectively and individually, will respond.

Jonathan E. Kaplan, M.D., is an infectious disease epidemiologist with the Centers for Disease Control, Atlanta. The opinions expressed here are his own.

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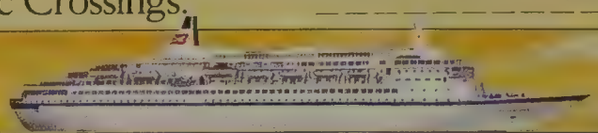

Cross-Cultural Cooking

Will sweet potato fettuccine, catfish sashimi, or pears with mushrooms form our future cuisine?

by Raymond Sokolov

Almost twenty years ago in Paris, I found myself interviewing Claude Lévi-Strauss in his laboratory at the Collège de France. It was all quite unexpected and intimidating. I had never read a word of the great structural anthropologist's work—something I had certainly intended to do before I met him—and had to ask the questions cabled to me by the *Newsweek* science editor. (*The Savage Mind* had just been published in the United States, and my magazine hoped to dress up its account of the book with a few quotes from the author.)

That day I had merely meant to make an appointment with the professor's secretary; I stopped off in person at the college because the phone there was out of order. But Lévi-Strauss was in his office, nattily attired and dictating a letter accepting the offer of an honorary degree from the University of Chicago. He would see me right then and there.

Fortunately, I had brought along the cable from New York. I took it out and translated the questions into French. They were naïve. Also, my retranslation of *The Savage Mind* back into French did not duplicate the original, which is *La Pensée Sauvage*. My improvisation—*La Mentalité Sauvage*—was not totally witless, but it wasn't the real title, as Lévi-Strauss gently explained.

He disposed of the two questions in the cable quickly. In what school of anthropology did he put himself? His own. What practical applications did he think his work brought to the lives of ordinary people? None.

I sat there in acute embarrassment, unable to think of anything else to say, but unwilling to admit it. Perhaps the ridiculous situation reminded him of his fieldwork in the Amazon, where he had faced tribal informants as totally unable to communicate with him on his level as I was. He chose, at any rate, to switch from the nominally intellectual arena to that of the physical. He led me into his lab and showed me his most treasured possession, a bank of files containing abstracts of ethnographic research from hundreds of thousands of expeditions to every corner of the world. This symbolic *tour de monde* brought the encounter to a graceful close.

Some time later, after I had read through much of the man's mazy synthesis of myriad myths from the Americas, it occurred to me that the giant file must have played a crucial role in the development of his thought. With such easy access to so many myths, from so many scattered peoples, all in one place, he had naturally tended to see them as all emanating from one collective brain, from a single savage mentality.

I was reminded of all this the other day as I reshelved my collection of cookbooks. Here was my own gastronomic equivalent of Lévi-Strauss's file. I have the food of the world's peoples at my fingertips, in the abstract and comfortingly definite form of recipes. Without much real effort, I can range through this database of the edible, comparing how Tibetan and Irish cooks have treated lamb, scanning all that people have thought to do over the centuries with rice or eggplant.

This freedom is a new development in human life. The production of reliable cookbooks about the cuisines of the world did not begin in earnest until twenty years ago. Since then, essentially oral or, at best, local traditions of food preparation have been transcribed and translated so anyone with a will to do so can acquire easily accessible records of virtually the full range of human food practices and store them in one relatively compact place.

For most people in the world, this is of no direct importance. But to food-mad novelty seekers in the industrial nations, the recipe database supplied by modern cookbooks is a creative prod that encourages them to think of the previously anarchic diversity of human cuisines as a unitary phenomenon, multifaceted, yes, but all of a piece. Just as one great file lumping together all the cultures of the world encouraged Lévi-Strauss to shuffle the myths of the planet as if they were cards in one vast deck, so our library of cookbooks makes it natural for cooks and restaurateurs to combine methods and dishes from hitherto discrete cuisines as part of a single grandiose repertory.

This hypermenu, if you will, is normally referred to as the *nouvelle cuisine*. For the essence of the new cookery is its openness to unprecedented combinations of food known to no traditional cuisine. Even in its beginnings in France, the *nouvelle cuisine* subsumed Japanese notions of plate decoration into classic French dishes. Soon exotic ingredients followed, the kiwi fruit being the arch example. But the latest stage in this deracination of cooking has been taking place in this country, where chefs much less constricted by culinary

The nouvelle cuisine *has adapted Japanese ideas of food preparation.*

Photograph by Aaron Rezney; from *An American Taste of Japan*, by Elizabeth Andoh (William Morrow & Company)

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traditions than their French counterparts—and more willing to pick up new ideas from books and travel—have manipulated authentic recipes so as to invent new dishes synthesized from historically disparate elements.

The process is still in its infancy and has so far largely involved adding exotic ingredients, particularly folkloric American or Asian ingredients, to classic European recipes. Sweet potato fettuccine is only one example.

Two new cookbooks go even further toward full cosmopolitanism. They both attempt to merge American food, broadly conceived, with Japanese. The results are successful in quite different ways. Elizabeth Andoh is an American with years of experience in Japan. Her first book, *At Home with Japanese Cooking* (Knopf), is the best book in English on traditional Japanese cuisine. Now, in *An American Taste of Japan* (Morrow), she embarks on an exercise in "cross-cultural cooking" that seeks to "integrate Japanese ingredients, kitchen techniques, and culinary philosophy with American foodstuffs, kitchen appliances and eating habits."

Colette Rossant, born in France but residing in New York and well known here as a food writer, has made two extensive trips to Japan and built on those experiences in developing the recipes for what she aptly calls *Colette's Japanese Cuisine* (Kodansha).

Several restaurants combining Western and Japanese cuisines preceded the appearance of these books. French-trained Japanese chefs have also done their part to bring together the industrial world's two most dynamic cultures. But the codification of the trend in two books in a single season marks a new stage in the full internationalization of cooking.

Andoh is as saturated with traditional Japanese food and culture as an American is ever likely to be. Beginning as a student in Japan more than twenty years ago, living soon after in the bosom of a Japanese family, she now teaches Japanese cooking in New York. So when she branches out into cross-cultural improvisation, it is no impromptu affair. Indeed, much of what she has put in her book records actual cross-cultural dishes already entrenched here and in Japan—or she improves on them. For example, take *aka dashi,* dark bean soup with bean curd and okra. Japanese have embraced the okra introduced to them by Americans. They even like the ropy texture it acquires when fully cooked. But Andoh knows that many Americans detest gluey okra; so she blanches it before adding it to the soup, revamping it for American taste.

Conversely, in *mirugai no omi-otsuke,* mussel and leek chowder, she invents a Japanese soup, with a dashi (kelp and bonito) broth and bean paste, to exploit two non-Japanese ingredients (mussels and leeks) popular with Japanese living abroad. And she has a clear recipe for the most established American-Japanese neologism, the California roll: a sushi filled with avocado and crab meat.

Many of the recipes are ingenious applications of Japanese methods to the American larder and to American dining practices. *Tosa*-style grilled beef takes a technique originally meant for fresh bonito and adapts it to a meat-centered diet (see recipe). It is the inspiration of Andoh's Japanese sister-in-law, a New Jersey suburbanite for many years.

Much of Andoh's provocative new book shows us ourselves through Japanese eyes. On every page, you feel the sensibilities of émigrés evolving a workable new way of eating on our shores. Menu plans are almost completely Americanized. And a chopstick cuisine has been made to accommodate larger pieces of food more appropriate in a land where knives and forks are universal.

Andoh has also thought deeply about the presentation of food at the table, a Japanese preoccupation. And she has found several hybrid solutions in her chapter on "Setting the Cross-Cultural Table." Japanese symbols are worked into origami-style folded paper decorations and "doilies." Color illustrations show actual food service on modern craft objects inspired by traditional Japanese pottery.

Like most of what Andoh presents, these objects and the cross-cultural craft movement they spring from, are part of a process of cultural hybridization already at work in the world. Andoh has undoubtedly refined and advanced it, but she is not inventing it. Colette Rossant, with her much more limited background in Japan and knowledge of things Japanese, operates, as she puts it, "using Japanese ingredients and my own intuition."

The resultant combinations are not so much cultural crosses as cultural collisions. Cold raw pears served as an appetizer with cooked oyster mushrooms, pine nuts, *shiso* leaves, and *sansho* pepper may strike you as a completely random notion. It certainly rests on no precedent known to me. I will reserve judgment until I am able to taste it, but the radical ingenuity that lies behind it is no accident.

"I had once a Japanese guest, an older gentleman, for dinner," Rossant writes. "I decided to be very 'Japanese' and use *azuki* beans. *Azuki* beans are small red beans that are often simmered with sugar

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to make a sweet red-bean paste that is widely used in Japan for sweets and confections. My distinguished guest took one sip and asked me what it was? 'Well,' I answered, very sure of myself, '*azuki* beans, naturally.' My guest looked away and never finished the soup. I had destroyed a tradition. My other guests, however, loved it. I tried it again in Japan and met with great success. Try the soup, but avoid serving it to older gentlemen!"

The point seems to be: If it tastes good, tradition be damned. So far as it goes, this principle is just fine with me, but I think it runs into one big obstacle. What do we mean when we say something tastes good? Doesn't tradition play a crucial role in determining taste? Where Rossant's new recipes do truly please guests trying them for the first time, isn't it likely that she has contrived unusual combinations that actually parallel earlier food ideas? Or is she tapping a lust for novelty? Twenty years from now the answer will be in. Try to remember to ask yourself in 2006 if people are still eating *azuki* bean soup and pears with mushrooms.

Raymond Sokolov is a writer whose special interests are the history and preparation of food.

Tosa-Style Grilled Beef

(*Gyuniku No Tosa-Zukuri,* slightly adapted from *An American Taste of Japan,* by Elizabeth Andoh, Morrow)

- 1½ pounds filet mignon or London broil
- 2 cloves garlic, peeled and cut into slivers
- 1 tablespoon vegetable oil
- ¼ teaspoon salt
- ½ teaspoon freshly ground black pepper
- Ice water

Marinade:

- ½ cup soy sauce
- 2 tablespoons sake (Japanese rice wine)
- 2 tablespoons rice vinegar
- 1 tablespoon lemon juice
- 1 tablespoon ginger juice (extracted from freshly grated ginger)
- ½ cup honey
- 2 scallions, trimmed and finely minced (green and white parts), about ¼ cup

Garnish:

- ¼ cup freshly snipped chives (optional)

Dip:

- Juice of 1 lemon
- ¼ cup soy sauce

1. Choose a slender piece of beef, no thicker than 1¼ inches. Make several shallow slits in all the surfaces of the meat and insert slivers of garlic into them. Brush the meat with a thin layer of oil, then salt and pepper both sides.
2. Sear the meat over hot coals or in a very hot preheated broiler. Turn it once after 5 minutes or when well browned. Sear the other side of the meat, too. (If using a rounded filet, you may have to turn the meat at quarter turns to brown evenly.) The meat should be rare, though not raw, inside. You can judge the degree of doneness by lightly squeezing the meat with blunt tongs at the thickest section; the firmer the feel, the better done the meat is. Ideally, you'll encounter a bit of resistance at the surface, but feel the core to be more flexible. The internal temperature will be about 140 degrees.
3. Remove the meat from the grill and plunge it into a bowl of ice water. Gently lift the meat out of the water, leaving any fat behind. Pat the meat dry on several layers of paper toweling.
4. In a glass or ceramic container large enough to allow the grilled steak to lie flat in a single piece, combine the marinade ingredients. Stir well to distrib-

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ute. Let the meat sit in the marinade, covered, at room temperature for 3 hours or in the refrigerator overnight. If the marinade doesn't completely cover the steak, turn the meat several times to insure even flavoring.

5. Serve chilled or at room temperature. Just before serving, remove the meat from the marinade. Slice the steak across the grain into ¼-inch slices. Arrange these slices, domino style, on a large platter. Cover the top with snipped chives if you wish. Combine the lemon juice and soy sauce to make a dipping mixture, which is served separately.

Yield: 6 to 8 servings

Azuki Bean and Endive Soup

(Slightly adapted from *Colette's Japanese Cuisine,* by Colette Rossant, Kodansha)

10 ounces *azuki* beans, soaked overnight
1½ quarts *dashi* (see below) or chicken stock
4 whole Belgian endives
2 tablespoons butter
1 tablespoon sugar
Juice of ½ lemon
Salt and pepper

Garnishes:
Watercress
1 additional endive, thinly sliced

1. Drain the beans and wash once more. Drain and place in a large saucepan with *dashi* or chicken stock. Bring to a boil, reduce heat to low, and simmer until beans are mushy soft, about 45 minutes (for faster results, cook 15 minutes in a pressure cooker).
2. Wash the endives and trim the bottoms. Melt the butter in a saucepan over medium heat. When the butter is frothy, add the endives and the sugar: brown on all sides. Reduce heat to medium-low, add the lemon juice and 3 tablespoons water, season with salt and pepper to taste, then cover and cook until the endives are tender when pierced with a fork.
3. Drain the beans over a large bowl, reserving the liquid.
4. Purée the beans and the endives in a food processor, adding some liquid if necessary.
5. Pour the purée into a large saucepan, add some stock (the soup should have the consistency of a thin purée), correct the seasoning, and heat.
6. Pour the soup in bowls, garnish with watercress and very thin slices of raw endive. Serve with French or Italian bread.

Yield: 6 servings

To make *dashi*:

Buy a 12-inch length of the kelp called *kombu* and 3 cups of dried bonito flakes (loosely packed when measured) at a Japanese food supply outlet. Wipe the *kombu* with a damp paper towel and make several crisscross incisions with the point of a sharp knife. Then place the *kombu* in a saucepan with 7½ cups cold water. Slowly bring the water to the boiling point over low heat, then remove the *kombu* before the water starts boiling. When the water does boil, raise the heat to medium and add the bonito flakes. Cook for one minute, skim the surface, then remove from heat. When the bonito flakes settle to the bottom of the saucepan, strain the stock through cheesecloth or a very fine strainer.

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The Iceman Climbeth

Photographs by John Wright

Once an active volcano, now the highest peak in the Ecuadorean Andes, Chimborazo knows both fire and ice. Boulders that once flowed as lava now share the slopes with pockets of ice. Compact and dense, the mountain ice seems to take on the hardness of the terrain, while Chimborazo itself offers the mountaineer physical hardships: steep slopes (of more than 20,000 feet), scant oxygen, and the threat of an avalanche when the sun loosens the frozen joints of the rocks.

A few Quechua Indians mine the ice of Chimborazo. At daybreak, an iceman and two or three of his brothers rouse a dozen donkeys and leave their tiny village in the foothills to start the ascent. At the lower altitudes they stop to cut and gather pampas grass. After a five-hour climb, they reach the lode of ice, at about 18,500 feet. Armed with axes and crowbars, the men chop, pry, and flake the embedded ice from the rock, then cut it into portable twenty-pound blocks. The blocks are insulated with the pampas grass and loaded onto the donkeys, forty to sixty pounds per beast. The men and animals return to the village late that night. In the morning, the iceman hauls the ice to the town of Riobamba and makes his transaction, receiving twenty cents for each block from the vendor with the ice-shaving machine.

The rewards of scaling mountains are relative. The Quechua iceman makes the trek because his mountain ice is to refrigerator ice as diamonds are to sand, and tomorrow is market day at Riobamba. He'll do it all again next week.—*J.R.*

Scottish-born photographer John Wright lived in Ecuador for three years. His work has also taken him across the Sahara and 2,000 miles down the Amazon River. The Hidden Forest, *his forthcoming book of photographs, is about the South American rain forest.*

A female brown capuchin in estrus (top) grooms the dominant male of her group. Females try to mate with the dominant male, which will later extend protection to infants he has sired.

Charles H. Janson

Capuchin Counterpoint

Divergent mating and feeding habits distinguish two closely related monkey species of the Peruvian forest

by Charles H. Janson

I found my main study group of brown capuchin monkeys where I had left them the previous evening, in the trees overlooking the oxbow lake Cocha Cashu. It was the foggy dawn of a dry-season day in southeastern Peru. As the light strengthened behind the tall forest canopy, I began to make out three clusters of the cat-sized animals, each huddled in the fork of a major branch. Straight overhead was the group's dominant male, noticeably larger than the others. Next to him lay the dominant female and her two offspring: one an infant barely old enough to leave its mother's back; the other a robust two-year-old. Two other adult females, each with a youngster, were nestled together elsewhere in the same tree. Not far away, in a neighboring tree, an immature female rested next to an adult male, while another adult male sat alone in a nearby branch.

When the sun touched the tops of the trees, all eleven monkeys set off toward the southern edge of their home range, a ½-square-mile area that extended from the lake to the Manu River, a tributary of the Amazon. Soon the group reached the tangled vegetation that resulted from the yearly flooding of the river and began to feed on the nectar of the brushlike red-and-yellow flowers of a *Combretum* vine. As the monkeys moved rapidly from one vine to the next, drinking nectar from each cluster of flowers, I struggled to follow through the thick undergrowth. The bright orange-red pollen of the flowers quickly coated the monkeys' normally white facial fur. Even after visiting all the flowering vines in the area, the monkeys' hunger was hardly satisfied, so they forged ahead to the bank of the Manu, where a large fig tree was just beginning to come into fruit.

When a brief inspection showed that the figs were still unripe, the monkeys turned away from the river and reentered the darkness of the mature forest. With its diversity of plant species, the forest is normally an easy place for the monkeys to find food. But fruit is very scarce in the middle of the dry season, and on many days the brown capuchins could ease their hunger only by eating the watery leafstalks of the *Scheelea* palm.

Gunther Ziesler; Peter Arnold, Inc.

Below: The dominant male of a brown capuchin group feeds on a Scheelea *fruit, tolerating an infant that sniffs at the food. The male's behavior toward other group members affects their access to many food sources. Right: A brown capuchin chews on pith, which constitutes about one-tenth of the animal's diet.*

Charles H. Janson

Hearing some birdlike whistles up ahead, I knew that the long morning's search for fruit had ended—one monkey had discovered a rich food tree and was alerting the others to the find. The prize turned out to be a fruit cluster in a *Scheelea* palm (the oily pulp surrounding the hard seeds is one of the capuchins' richest and most favored foods). Although this species of palm is common in the group's home range, it provides only a few clusters of ripe fruit at a time because the plants do not reproduce in unison.

The dominant male was soon at work extracting a fruit from the cluster. Because the fruits are tightly packed, great strength and perseverance are needed to remove the first one, but the rest are easily picked. After fifteen minutes of vigorous pushing, twisting, and biting at the lower edge of the three-foot-long cluster, the dominant male succeeded in loosening a fruit. He then played "king of the cluster," sitting on top of the bunch of fruits while he stripped the hard, brown husk off his find, exposing its dry but tasty flesh.

I was busy writing down my observations when I was interrupted by a sudden, loud scream; looking up, I saw the dominant male chasing a slightly smaller adult male away from the cluster. With food so scarce, and so rich a food source at stake, such confrontations are frequent, often more than ten per hour. The show of aggression is rarely more than a quick lunge, a threat, or a chase. All members of the group seem to know the strength of their adversaries, and a quick reminder from the more dominant monkey resolves most disputes.

At first the dominant male fed alone, but soon he was approached by the youngest of the five juveniles, which had all followed him when he entered the palm. The baby was not chased away as the subordinate male had been. When the infant crawled up on the cluster, poked curiously at the dominant male's toes, and grabbed at the fruit in his hands, the male continued eating, repeatedly giving soft calls in apparent contentment. Soon the youngster picked up a fallen, partly eaten fruit, sat beside the dominant male, and finished the pulp.

In the next few minutes, three other juveniles came to the cluster and retrieved fresh or fallen fruits beneath the male's gaze, but he ignored them completely. This peaceful scene was not disturbed even when, ten minutes later, the dominant female came up hesitantly and pried a fruit loose. Behind her came the second-ranking adult female, but she got no closer than ten feet, when a quick lunge by the dominant male sent her scurrying back to the tip of her palm frond.

After the male had eaten about fifteen fruits, he moved off the top of the cluster and continued feeding a few feet away. Now the other adults began to approach the fruits, but the subordinate adult males were still not allowed near the cluster. If one dared to advance within five yards, the dominant male at once threatened or lunged at him.

The dominant male remained in the palm for another hour, until he had eaten his fill, about forty fruits. Then he left the palm and rested belly-down on a large tree limb fifteen yards away, all four feet dangling over the branch. With his departure,

a free-for-all ensued, with the other adult males rushing in, chasing out females and juveniles, and grabbing three or four fruits at a time, hobbling away with them clutched in their hands and feet. At one point, however, an adult male was a bit too rough in pushing a young monkey away from the cluster, and the baby squealed its distress. A great crash followed at once, as the dominant male jumped into the palm to defend the infant. All the capuchins except the juveniles cleared out of the palm. With eyebrows raised and canines bared, the dominant male glared threateningly at the offending male, who grimaced submissively from the safety of the next tree.

As the cluster dwindled to less than one-fifth its original number of fruits, I heard a few nervous *chuck* calls and noticed several of the monkeys looking off in the direction of some approaching, crashing noises. White-fronted capuchins, close relatives of the brown capuchins, were arriving. Slightly smaller than brown capuchins, and much paler in coat color, white-fronted capuchins travel in groups of from eight to twenty animals—groups that are larger on average than those of brown capuchins. The first three approaching animals were adult males; fifteen group mates followed behind. The brown capuchins suddenly seemed to have disappeared—only the dominant male remained visible near the fruit cluster, facing the oncoming group. The three white-fronted capuchin males stopped about twenty yards away, and one male draped his arm over another's shoulder. All three gave a threat display, staring with wide-open mouths to expose their long canine teeth. The solitary brown capuchin returned the threat by arching his shoulders, frowning, and sticking out his lower jaw to expose his shorter, but stouter, canines. Suddenly, two of the white-fronted capuchin males rushed in toward the brown capuchin, which quickly retreated some thirty yards, where he watched as the new group plundered the remains of the palm fruit cluster.

The feeding etiquette of the white-fronted capuchins at the palm fruit cluster differed markedly from that of the brown capuchins. All the adult males took turns feeding on the fruits; no one of them monopolized the cluster for more than a few minutes. Group members fed in the order of arrival, the adult females behind the males, the juveniles bringing up the rear. Aggression was rare and not primarily between adult males. Juveniles generally avoided adult males, even the dominant male. If they did get near the leader, the juveniles squealed submissively even though he had made no move to threaten or chase them. With all the group members feeding at once, the remaining fruits soon disappeared, and the white-fronted capuchins left to find other food.

As I followed the monkeys on through the forest, I wondered at the great social differences between these two closely related species. Why was there so much aggression within the group of brown capuchins and so little in the group of white-fronted capuchins? Why were juvenile brown capuchins tolerated by the dominant male, while juvenile white-fronted capuchins seemed to fear their dominant male? Why did the dominant male brown capuchin defend his group alone, while several male white-fronted capuchins cooperated?

Differences in social behavior often go hand-in-hand with differences in the habitats exploited by two species or with differences in the way they utilize a shared habitat. For example, scientific comparisons of many primate species have shown that group size—an important aspect of a species' social structure—relates to where a species feeds. Those with large groups usually feed in large fruit trees, which are generally scarce, whereas those living in small groups avoid the large trees and feed mostly in small ones. Small groups cannot defend large trees in competition with large groups. Spreading out in large trees also makes the small groups more vulnerable to predators such as eagles. I was curious to know whether there were simi-

Warren Martin Hern

Left: A low-ranking brown capuchin female consumes spittle bugs she has found at the base of the compound leaves of a lowland mahogany tree. Insects account for about one-sixth of the monkey's energy intake. Below: A white-fronted capuchin juvenile carries a younger juvenile on its back. In this species, named for its white forehead, the youngsters in a group often stick together rather than staying with their group's dominant male.

Charles H. Janson

lar connections between the two species' use of their environments and the contrasting types of social behavior I had observed. With several colleagues and assistants who worked with me in the Cocha Cashu Biological Station in Peru's Manu National Park, I spent more than four years unraveling these connections.

One of the things I tried to determine early on was whether the two species differed in feeding behavior, but finding a difference was not easy. Both species' feeding activities were the same by a number of measures: percentages of time spent feeding on fruit, leaves, and insects; food species eaten; and techniques used to acquire foods. After several years of study, however, a subtle, but consistent, difference appeared. The more robustly built brown capuchin can feed more easily on tough fruits and hard seeds than can the more slender white-fronted capuchin. For instance, the large, tough fruit clusters of the *Scheelea* palm are a major food source for brown capuchins but are exploited only rarely by white-fronted capuchins, which can open up a cluster only with great difficulty.

This slight difference in ability to break open and eat different food species is connected to a more striking difference in the sizes of fruit trees used by the two capuchin species. The tough, hard fruits that the bickering brown capuchins can eat are typically found in understory trees fifteen to sixty-five feet tall with crowns less than thirty feet in diameter. These small-crowned trees produce a limited supply of fruit, which a brown capuchin group can quickly exhaust, forcing the monkeys to use many trees every day. Because these small trees are quite common, however, brown capuchins derive more than half their fruit diet from them. The smaller, softer fruits preferred by the more peaceful white-fronted capuchins are often found in canopy trees more than 100 feet tall with crowns up to 165 feet in diameter. Fruiting trees of such size are uncommon, but often produce enough fruit at one time to feed a group of white-fronted capuchins for a whole week.

The contrast in tree size is also related to the difference in group size: brown capuchin groups are on average smaller than those of white-fronted capuchins. More striking, however, is the difference in the level of competition for food between the group members of each species. Individuals of both species quarrel over food, but the size and productivity of the feeding tree strongly affect whether aggression is needed or able to boost an individual's share. As I observed in the small-crowned *Scheelea* palm, aggression among the brown capuchins is very effective at keeping subordinate group members away from the food and allowing the dominants and juveniles to feed at their leisure. When I tallied up how many *Scheelea* fruits each group member ate, I found that strong, aggressive individuals did much better than timid or weak ones, with two major exceptions. Even the most bothersome, weak juvenile was allowed to feed

beside the dominant male, and so it could eat many more fruits than if it had to fight for them. But subordinate adult males consumed far less than expected, because the dominant male was especially vigorous in chasing them off.

On a later occasion, when the same brown capuchins were feeding spread out in the large crown of a canopy fig tree, they got along much better with one another. In the midst of an abundance of fruit, brown capuchins rarely find it worthwhile to fight, and dominant monkeys feed only slightly faster than do subordinates. White-fronted capuchins feeding in large-crowned fig trees behave similarly. They are generally more peaceful, then, because they habitually use large, productive fruit trees where an individual does not need to fight for its share of food.

This difference in the extent of competition within each of the two capuchin species does not explain the contrasting *patterns* of aggression that occur within each group. Why is aggression especially high among adult brown capuchin males, yet barely noticeable among white-fronted capuchin males? Why can baby brown capuchins enjoy the tolerance and protection of their group's dominant male, while young white-fronted capuchins receive no such favoritism? These riddles cannot be answered without an understanding of capuchin mating behavior.

When I first saw a female brown capuchin in estrus, I thought she was ill. She followed closely behind the dominant male for hours without stopping, whining constantly and wearing an unusual grimace. She also kept trying to touch the dominant male's rump, as though playing tag. He appeared to take little notice of her, however, except for occasionally chasing her a few yards away, as though he wished to be left in peace. After an entire day of this tension, the male and female finally chased each other for several minutes and then mated.

This courtship was unlike the descriptions I had read of male baboons viciously fighting over access to an estrous female. The dominant capuchin male often ran from the female, and they did not actually mate until he finally stopped running. Following copulation, the female ran around behind the male and sat mounted tightly on his back for eleven minutes, substantially longer than the three minutes the male took to mount her. Other adult males showed no interest in the mating pair and never tried to interfere with them. This pattern of active female and passive male participation in courtship was not unusual for brown capuchins—I saw it many more times with different females and in different groups. In every case, the dominant male was the female's focus of attention.

A female's active courtship of the dominant male makes it much more likely that he, and not some other male, will sire her infant. The advantage for the female is in gaining the dominant male's protection for her offspring. The male does not offer such protection indiscriminately. Natural selection especially favors a male's care of an infant if it is his own. In fact, the dominant male brown capuchin only protects infants born to mothers that actively courted him. I observed that when a new male rose to be dominant in a particular group, he would not extend protection to any infants sired by the previous dominant male, even if they were born after he assumed power.

The reason the dominant male's protection is important seems to be connected to the brown capuchin's feeding habits. When food is scarce and found primarily on small-crowned trees such as *Scheelea*, the dominant male can determine if and when other monkeys get to feed. His tolerance of a particular group member strongly affects that monkey's food intake and thus its health. The dominant male's protection is especially important to a baby monkey's survival because infants are too small to win fights on their own.

Left: An adult brown capuchin female uses her tail to balance on an Astrocaryum *palm. Below: A juvenile brown capuchin eats the fruit of a* Scheelea *palm. The large fruit cluster is easily picked clean, once the first fruit has been worked free. The brown capuchins, which are more robust than their white-fronted cousins, are better equipped to break into this rich food source.*

Both photographs by Charles H. Janson

Young monkeys soon learn to exploit this protection. They squeal at subordinate males long before they come close enough to interfere, bringing the dominant male rushing to chase intruders away. Juveniles are so pampered in this way that they prefer to stay with the dominant male rather than with their own mothers. Subordinate males learn to avoid this clique, instead looking for food alone at the edge of the group.

The mating system of the white-fronted capuchins is quite different. When I watched a white-fronted capuchin in estrus, she did not actively pursue the dominant male. He, on the other hand, was clearly interested in the female's sexual condition and often sniffed her urine, apparently detecting the presence of hormones that indicated when she was most fertile. The dominant male white-fronted capuchin pursued the estrous female and sometimes even forced her to copulate when she was unwilling. Yet, in spite of his interest, the dominant male could not prevent the female from approaching subordinate males for matings. At least one estrous female I observed spent more time with the group's second-ranking male than with the dominant male.

Because female white-fronted capuchins do not prefer to mate with any one male, several males in a group are equally likely to be the father of a given offspring. In this situation, natural selection does not favor strong male care of infants, and in fact, white-fronted capuchin males do not especially protect infants. The youngsters survive despite the lack of strong male protection because they feed mostly in large-crowned fruit trees where there is little competition for food.

Understanding the mating systems of the two capuchin species helps explain the very different patterns of aggression between group members. Because the dominant male brown capuchin is usually the father of most group infants, he not only tolerates the babies but actively protects them from aggression. The subordinate males, which only rarely sire any group infants, displace infants whenever food is at stake. Thus, the dominant male's protection of infants places him in conflict with the rest of the group's adult males. This habitual conflict reduces the possibility of adult male cooperation in other types of situations.

In the case of white-fronted capuchins, where several males are equally likely to have sired a particular infant, males show no special favoritism to particular juveniles. Males rarely displace feeding youngsters, but they also do not defend a juvenile when it squeals. Consequently, young white-fronted capuchins do not follow any adult male, not even the dominant male. Instead, they form a distinct subgroup, often accompanied only by an adult female. With no conflicts over juveniles to separate them, several white-fronted capuchin adult males often are found together in the preferred, central area of the group.

Once I understood these differences, I was also able to understand why the brown

An immature brown capuchin explores a flower.
Jany Sauvanet; NHPA

capuchin dominant male has to defend a food tree alone, while the white-fronted capuchin males cooperate in the defense of food. Because the dominant male brown capuchin fathers most group infants, he stands to benefit most by defending the group's resources. Subordinate male brown capuchins do not share equally in the benefits of defending a tree. Not only does the dominant male's aggression deprive them of equal access to food, but they are also unlikely to be the fathers of group infants.

White-fronted capuchins do things differently. Because all the males are likely to be fathers of some group infants, all have a vested interest in defending food for the group as a whole. Thus, all males usually help drive other monkey groups from their large food trees. Males gain an advantage by cooperating; each male lowers his own risk of injury while defending the food tree more effectively than if he were alone.

The difference in male cooperation between the two capuchin species shows up in their reactions to dangerous predators, such as the harpy eagle, one of the world's largest birds of prey. When an eagle attacks a brown capuchin group, the dominant male is the only individual that remains exposed. He gives a distinctive barking call that, by its frequency and loudness, tells his group how close the eagle is. Often the brown capuchin dominant male is so aroused that he gives nervous *chuck* calls for a full hour or more after the eagle has flown away.

White-fronted capuchins do not display such "heroic" behavior when danger threatens. The dominant male typically rushes for cover when an eagle attacks. When the initial assault is over, he may come out and threaten the perched predator, but generally not without the aid of other adult males. By cooperating, each white-fronted capuchin male reduces his own risk of injury. After the predator has flown away, the dominant male does not remain vigilant or continue giving alarm calls longer than other group members.

The difference in male cooperation between the two capuchin species has an important effect on feeding behavior. As I observed at the *Scheelea* palm fruit cluster, white-fronted capuchins can easily displace brown capuchin groups from food trees. Normally when two monkey species fight, the winner is the species with the larger body size. Yet the larger and considerably more robust brown capuchins rarely win against white-fronted capuchins, even when two groups have equal numbers of members. The secret of the white-fronted capuchins' success is surely the cooperative behavior of their males. The only white-fronted capuchin groups that I ever saw lose to brown capuchin groups were ones in which there was only one adult male.

The story ends up where it began, with white-fronted capuchins displacing brown capuchins from fruit trees. The two capuchin patterns seem consistent and self-perpetuating, but how did they arise? One possibility is that originally there was a divergence in diet, with the brown capuchins evolving into a robust form that could exploit tougher fruits and nuts. These tougher foods happened to be located in understory trees. Because these trees were smaller, periodic competition for food occurred within groups of brown capuchins, resulting in smaller groups and a preference by females for mating with the dominant male. As this new mating pattern became characteristic, cooperation between males decreased, and the brown capuchins eventually were forced to relinquish their claim on the larger trees to the white-fronted capuchins.

Without evidence from appropriate fossils, we can only guess at the order in which these patterns emerged, and other scenarios are possible. For example, the ancestors of today's white-fronted and brown capuchins may have first diverged in their mating patterns, and this divergence may have eventually forced—or enabled—brown capuchins to exploit the smaller trees. We can be sure, however, that each aspect of capuchin social behavior and ecology has influenced every other. Instead of regarding any single factor as a primary cause of the others, I prefer to consider all of them to be mutually reinforcing adaptations to divergent life styles. □

The Falklands' Johnny Rook

The versatile but vulnerable caracara survives by playing the roles of vulture, hawk, and crow

Text and photographs by Ian J. Strange

The small Special Forces tent I had borrowed for my field expedition was in shreds. Green strands of the tough synthetic material fluttered in the wind, and the normally durable guy lines were frayed as though they had been used for months; yet this brand-new equipment had been pitched for only a matter of hours. I surveyed the wreckage and thought, "Hell, the army will never believe that half a dozen birds did this." But the culprits were still there, demolishing what was to have been my home for the next few weeks. I had made the acquaintance of one of the world's rarest birds of prey, found only in the Falklands and a few wind-swept islets off Cape Horn. Called *Phalcoboenus australis* by scientists, and striated caracara by informed bird watchers, the bird is better known in the Falkland Islands as Johnny Rook.

Nineteenth-century accounts of the Falkland Islands refer to a bold and inquisitive raptor, a *caracará,* or "carrion eater." Early mariners labeled the birds sea eagles or rooks, then later Johnny Rooks. I had puzzled over the name until I landed on a remote island in the Falklands archipelago, one of the few remaining strongholds of the species. There I saw a sight that must have presented itself to the sealers and penguin oilers who had walked these shores more than 150 years earlier: on a coastal green, large groups of gentoo penguins were busy building nests. Stationed around the colony's perimeters were the sinister, dark, silent rooks, watching and waiting. I had seen a similar scene in England—rooks on freshly turned pasture—and remembered that to the nineteenth-century whalers and sealers, the gentoo penguin was known as Johnny Penguin; here surely was the derivation of the name Johnny Rook.

Capt. Charles Barnard, a sealer from Nantucket, who in 1812 and 1813 was marooned on New Island, in West Falkland, wrote one of the earliest accounts of the species. He described the bird and discussed its early naming:

> These birds, generally known among sealers by the name of rooks, partake of the form and nature both of the hawk and the crow. They are about the size of the largest

From its nesting site, an adult striated caracara surveys a large mixed colony of black-browed albatrosses and rockhopper penguins. Caracaras raid sea bird colonies for eggs, chicks, and disabled adults.

Brown-plumaged immature caracaras are notoriously inquisitive, below. When prey is scarce, the birds' poking and prying may uncover vital new food sources, but the curiosity of young birds, particularly about humans, has also led to their persecution. Right: An adult tends two newly fledged young in the dense cover of protective tussock grass. A recent meal accounts for the full gray crop of the young bird in the foreground.

hen hawks common to the United States; of a black color, and shaped something like a rook. Their claws are armed with large and strong talons, like those of an eagle; they are exceedingly bold and the most mischievous of all the feathered creation. The sailors who visit these islands, being often much vexed at their predatory tricks, have bestowed different names on them, characteristic of their nature, as flying monkeys, flying devils, etc., etc. I have known these birds to fly away with caps, mittens, stockings, powder horns, knives, steels, tin pots, in fact every thing which their great strength is equal to. On landing at any place, we always find some of these birds, who visit us for the purpose of reconnoitering; and if we have any meat in the boat, they give the signal by commencing such an ear-tormenting cawing, that we are soon surrounded by additional numbers; they compel us to secure our provisions, by covering them with the sails of the boat, which we fastened down by stones, and then direct the dog to lie down by them to prevent these harpies from hauling off the stones and sails, to get at and devour the provisions. These winged pirates have been known to attack a man, when passing near their nests while their young ones were there. From their color, mischievous disposition, and feeding on carrion, they appear to belong to the crow species; while, on the other hand, from the size (being twice that of the common crow), strength, audacious boldness, their form, and largeness of their talons, they appear to be connected with the hawk, which, when pinched with hunger, have been known to feed on carrion. I should, from these characteristics, call them the vulture-crow. I shall, however, continue to distinguish them by the name they are most generally called by sealers, viz. rooks, until some ornithologist shall affix to them their appropriate name.

Ornithologists place the seven species of Central and South American caracaras in the family Falconidae. Although they share the talons, hooked beak, and acute sight of true falcons, the long-legged, often ground-running caracaras outwardly bear little resemblance to their streamlined cousins, which are built for aerial attack. The relationship between caracaras and falcons is founded on basic but less obvious characteristics such as skeletal structure and molt pattern. Although its name emphasizes its taste for carrion, the caracara is a predator as well as a scavenger and, like the aggressive sea bird the skua, is known to rob other predators of food. My long-term studies of the caracara's feeding ecology have shown that the bird is omnivorous, resorting to every available food source to survive. This is particularly true of the bird in recent times.

Charles Darwin found this species to be "exceedingly common in the Falkland Islands." Darwin's two short visits to the Falklands—in March of 1833 and 1834—were to the north of the main island of East Falkland and in particular to Port Louis, at that time the first and only settlement in the islands. Today the species is rarely seen in this region of the archipelago and then only as a vagrant. Yet Johnny Rook is common in its few remaining breeding areas, especially in the west part of the Falklands. Like Barnard, Darwin and other naturalists have written of this species' scavenging, carrion-eating habits; the result is a picture of a tenacious survivor species. Why, given its adaptability, did the striated caracara disappear from its former stronghold in East Falkland and in the other main islands?

In Darwin's day, fewer than one hundred settlers lived in the Falklands, and sheep ranching, one of the islands' chief occupations today, had yet to commence. As sheep farming grew on the main island of East Falkland, the populations of the striated caracara declined, despite the potentially plentiful source of carrion in the form of sheep and lambs.

The bird's notorious inquisitiveness has led to its persecution and has sparked much misunderstanding and folklore. What has been termed the caracara's mischievous nature is a form of curiosity mixed with opportunism in its continual search for food. The interest in my tent, for example, has a parallel with the bird's investigation of a molting sea elephant. Often a caracara will probe and pull at pieces of a seal's skin, looking for food. Until some ten years ago, bounties were officially paid on the beaks of these rare birds, because of their supposed depredation of sheep. I suspect that many immature caracaras, being the most brash, still meet their end because of their persistence in trying to balance on a radio mast and steal its brightly colored piece of insulation tape or in trying to ride a clothesline in a strong wind, seeming to take great interest in items of apparel.

The number of caracaras may also have been overestimated. In March—the same month that Darwin first observed the species—numbers of dark-plumaged, imma-

ture birds, those more generally seen and described, disperse from their breeding sites. Settlements lying close to offshore island breeding grounds may attract these young birds, which scavenge about the sheep runs and "haunt the neighborhood of houses for offal," as Darwin observed. These young birds are especially curious about humans and this has led to the renegade image popularly ascribed to the species as a whole. Beyond this, I have watched as more than forty birds scavenged about a single settlement, a sight that gives those unfamiliar with this species the impression of large populations. In fact, young birds from many different breeding sites gather to form flocks, and groups of immatures disappear almost as suddenly as they materialize; many of them die in their first winter. The stronger, more aggressive ones reach maturity, but only 2 to 3 percent achieve adulthood, find the right niche in what is a specialist environment, and breed successfully.

Loss of habitat, as well as attempts to extirpate the caracara, led to its decimation in the Falklands. Few records remain to give us a true picture of what Port Louis must have looked like during Darwin's visit, but one of the Falklands' most important habitats—islands of tussock grass—then flourished in such areas. Tussock grass was quickly eaten after the settlers introduced cattle and sheep. Salt tolerant and growing only in coastal sites that offer the richly nutritious waste from sea bird and seal colonies, the grass forms a dense cover, with individual stools, or clumps, reaching heights of more than ten feet. Half of the Falklands' breeding bird species use these grass-covered areas for nesting or feeding. One of the islands' three seals, the southern sea lion, also prefers these grass-sheltered sites for breeding. My studies have taken me to many parts of the East Falkland mainland coasts that Darwin may also have visited. Today there are no caracaras, but there is evidence of a once-rich coastal area of tussock grass that supported bird and seal life. Small petrel colonies remain, the remnants, I believe, of substantial populations on which Johnny Rook once preyed. Colonies of seals—another species on which the caracara relies during certain periods of the year—were also much larger along this coastline.

Much of my research on the general ecology of Johnny Rook was carried out on a remote island in the Falklands, separated from the nearest land by some forty miles of open sea. Getting to, and living on, the island was often a logistic nightmare, but the lure was its large, isolated population of caracaras. This minieco-system provides the species with the same conditions that prevailed before humans settled the Falklands.

The island is a mile in length and 900 yards at its widest point. Dense tussock grass covers two-thirds of the island; the rest is bare rock and rock-strewn clay subsoil. From October through March—the Southern Hemisphere's summer—much of this bare ground is covered by a huge, mixed colony of black-browed albatrosses and rockhopper penguins, a colony that numbers about two million birds at the height of the breeding season. The island also holds a colony of 540 pairs of gentoo penguins, several thousand pairs of fairy prion, large numbers of Wilson's storm petrel, diving petrel, some songbirds, and a number of sea lion colonies with a total population of some 250 animals. Located on the line where the tussock meets the perimeter of the island's main bird colonies are the nesting territories of some sixty pairs of striated caracaras, an amazing density for such a small island, but one that has remained at a constant level since my arrival on the island in 1965.

My work has shown that the caracara's complex feeding ecology is interwoven with the life of local populations of birds, mammals, and invertebrates. The key to the caracara's feeding pattern is shifting food availability, seasons of plenty alternating with great privation.

In September the colony nesting areas, deserted since April, slowly fill with black-browed albatrosses. Prions (small petrels)

The rockhopper penguin nesting season in late October, the austral spring, is a time of plenty for the caracaras. Swift ground runners, caracaras dash into a colony, seize an egg, and often elude defending parent penguins.

return to nest burrows beneath the loose rock debris that covers parts of the island. The homecoming of these species constitutes an influx of food for the caracaras. Prions are preyed on directly. Pairs of caracaras having territories within the nesting areas of these petrels even adopt seminocturnal behavior in order to grab the prions as they return to their breeding grounds at night. Of the tens of thousands of black-browed albatrosses coming back to the island, a very small percentage of weak, diseased, and injured birds afford a supply of carrion, as do debilitated male rockhopper penguins, which appear during the first few days of October after an absence of nearly six months. The density of the penguin colonies also results in fatalities as the birds struggle to maintain their territories.

When the populations of adjacent colonies of rockhoppers and albatrosses boom in October, caracara pairs begin to defend their turf more tenaciously. Immatures are no longer tolerated and are forced out into neutral zones to scavenge and prey, generally as a group, well outside adult purview. Adults, as well as holding nest sites, guard well-defined feeding areas immediately adjacent to the nest. All the nests in my study were placed so as to give the caracara a commanding view of the feeding area. Nests were commonly built on the fringes of the tussock grass, which serves as cover. With prey species such as penguins and albatrosses nesting right up to the tussock-grass perimeters, the caracara is presented with a larder literally at its doorstep, one that effectively comes to the predator rather than forcing it to expend energy in search of prey. I found feeding territories to be small, some pairs preying in areas less than 120 yards square. At the start of the albatross and penguin breeding season, the impact of predation in constricted areas is not evident. Toward the season's end, however, the separate preying territories are clearly defined by the empty nests of black-browed albatrosses, rockhopper penguins, and king cormorants in the immediate vicinity of caracara nests.

Caracara breeding begins in the third week in October, when the first egg of a clutch of three is laid. Timing coincides with the main flush of rockhopper egg laying. By late November, just as the first caracaras are hatching, female rockhoppers, after a period spent feeding at sea, beach and relieve the incubating males. This exchange of parental duties in the overcrowded colonies dislodges an extraordinary number of near-to-hatching eggs from the nests. Thus, at the critical stage when the newly hatched caracaras require soft, high-nutrient food, protein is served up in the form of developed penguin embryos.

As the young caracaras develop, the hatching of rockhopper penguins begins, followed by that of black-browed albatrosses. Rockhopper chicks are an important prey for the striated caracara, which, unlike many hawks and falcons, spends much of its time on the ground. As Darwin noted, caracaras "run extremely fast, very much like pheasants." This ground speed is used to advantage when the birds prey on young rockhoppers. A young caracara runs into a colony, seizes an unguarded chick with one foot, and then, partly hopping and partly flying, drags or lifts the bounty clear of defending parents. When rockhopper chicks become too large for the caracara to seize directly, natural chick mortality compensates. As one of the few predators of the islands' penguin and albatross populations, the caracara plays an important role in controlling the number of these birds by weeding out less alert, weak, or diseased individuals.

The later-breeding king cormorants, which form colonies in association with albatrosses and penguins, provide a third flush of edible eggs and young. At this stage of the season fresh provisions are

also delivered in the form of immense amounts of squid, lobster krill, and other marine animals that are brought ashore by albatrosses and penguins for their young. As the adults feed their chicks by regurgitation, the food that spills is scavenged by caracaras.

Young caracaras become independent by early February. Growing rockhoppers leave the rookeries for the sea, but large numbers of dead young litter the now depleted colonies. Juvenile caracaras, which feed mainly on prions and other petrels, now have an opportunity to test their predation skills. Fully fledged petrels emerge from underground nest chambers and head for the sea, depriving the less-skilled young Johnny Rooks of ready rations. The majority turn their attention to black-browed albatrosses. Normal, healthy albatross chicks are now too large for the caracaras to overcome, but many of these will die before they are fully fledged and capable of leaving the colony in April. Still, for the caracara, the days of plenty are steadily dwindling.

By midwinter, in June, the island appears lifeless; the once-packed colonies lie quiet and desolate, a sea of mud and guano. The only obvious signs of the once-teeming breeding ground are the pedestallike, raised mud albatross nests and the remains of young birds. Mud-soiled young caracaras roam the deserted colonies, hungry for carrion. When the food surplus of the warmer months diminishes, scarcity controls the caracara population. Many young caracaras will die, unable to compete with more aggressive individuals for limited food supplies. The more skilled adult birds and some plucky immatures home in on marine mollusks, the inverte-

Below: A female caracara preens a chick. Caracaras lay clutches of three eggs at nesting sites on a few remaining islands having tussock grass. Parents take turns brooding and attending their young. Right: Forced out of breeding territories by adult birds, immature caracaras form groups and scavenge carrion. These congregations can give the false impression that caracaras are numerous. Many young birds, unable to compete with more aggressive individuals, will starve during the winter.

brates of the tussock-grass stands, and groups of resident gentoo penguins. Gentoos feed at sea, but continue to occupy roosting sites ashore. Although feeding of young gentoos has long been discontinued, these sites become littered with what appears to be regurgitated food, which the most resourceful caracaras exploit.

Two Falkland mammals, the southern sea lion (a year-round resident) and the winter-based fur seal are vital to the caracara's winter well-being. These seals seek the higher ground and protective tussock grass in the winter months. Their excrement becomes a vital food source for the remaining caracaras. The few current breeding sites of the Falklands' population of caracaras have associated colonies of both gentoo penguins and seals. Only the existence of these colonies, adaptable eating habits, and the exploitation of every available resource can insure the caracara's survival.

No records document the number of gentoo penguins breeding on the north coast of East Falkland when Darwin recorded the Johnny Rook as common, but there is little doubt that there were many more than at present. Sea lions, now scarce along that coast, were also prolific. After sealing and settlement depleted these forms of wildlife, the caracara simply disappeared from the scene.

A more enlightened view of this rare raptor will increase its chances of survival only if the interdependence of the Falklands' potentially rich wildlife is taken into account. A healthy marine fauna is the lifeline of the islands' bird and mammal populations, on which the caracara in turn relies. Based on knowledge gained from fieldwork, such as the importance to the caracara of tussock grass, seal and sea bird colonies, and minimal winter rations, some twenty offshore tussock islands have been set aside as reserves. Protection of offshore animal life, by restrictions on the overfishing now threatening the islands, is the next step needed to safeguard the Johnny Rook. □

A young black-footed ferret
Franz J. Camenzind

Decline and Fall of the Black-footed Ferret

The last known colony of the animal is dying off despite well-meaning efforts to save it

by David Weinberg

The answer arrived last October, on the very day Wyoming scientists and wildlife managers were sitting together in Cheyenne trying to figure out why the last-known black-footed ferrets in North America were rapidly disappearing. The latest estimate of the much-celebrated ferret population in the little town of Meeteetse, Wyoming, was thirty-one ferrets, down almost a hundred animals from the year before. But privately, researchers were saying they would be grateful for thirty-one animals; that there were probably only fifteen or twenty left at Meeteetse. One complicating factor was that during the summer, plague had decimated the prairie dog colonies where the ferrets live. Because ferrets feed almost exclusively on these members of the squirrel family, some observers felt the ferrets were starving to death. The problem with this idea was that none of the large prairie dog towns had been entirely wiped out by the plague. The ferrets, which are probably not directly susceptible to the disease, still had food.

Seizing on this last detail, the Wyoming administrators adopted the most sanguine view of the situation, one that coincidentally permitted them to do nothing. Ferret numbers seemed to be dropping because the young were dispersing from their parents' territories, officials declared. Confronted with evidence that in the previous three years ferret young had not dispersed so early, the administrators simply dismissed the dispersal research. "What we have here is a bunch of damned fools running around saying the sky is falling," said Harry Harju, the head of Wyoming's ferret project.

Four days later, at the meeting in Cheyenne, the sky landed: Tom Thorne, Wyoming's wildlife veterinarian, burst in with the news that the black-footed ferrets of Meeteetse had canine distemper, a fatal disease. One of six ferrets that had recently been taken into captivity had died of the disease; another was critically ill. The animals hadn't been in captivity long enough to develop it there—they must have contracted the illness while they were still in the wild. "You should have seen it, everybody's mouth dropped open," recalls one witness. "An entire roomful of people looked like they had been kicked in the gut."

The news simplified things immensely. If distemper was widespread in the Meeteetse population, the animals were doomed. The only thing to do was to trap the remaining black-footed ferrets and remove them from the wild. In captivity, they could be vaccinated against distemper and, if they hadn't already been exposed to the disease, they could be saved. State officials insisted that a few outlying prairie dog towns be left untouched, so that the public could be assured that there still were some ferrets living in the wild. A press conference was scheduled for later in the week.

What state and federal officials didn't say at that press conference was that they had little hope of finding ferrets in those outlying areas; that in one of them, called Long Hollow, no scientist had seen a black-footed ferret in the past year; and that even if a few ferrets were on the periphery, there was little hope they could survive in such small numbers. What officials didn't say—because they could barely face it themselves—was that four years after the Meeteetse ferrets had been found, there was a strong possibility that the animals were becoming extinct.

Prairie dogs are the major prey of ferrets, and large, healthy prairie dog colonies are a key element in the black-footed ferret's survival. But poisoning campaigns in the first half of the century cut prairie dog numbers by as much as 90 percent in some areas. Most recently, an outbreak of sylvatic plague has further reduced their numbers.

Jim Brandenburg

Only a year earlier, in 1984, virtually none of the researchers working at Meeteetse would have taken seriously the idea that the little, masked, catlike mammals living in northwest Wyoming were in imminent danger. In the summer of that year, there were more black-footed ferrets in the area than you could shake a spotlight at. Twenty-five litters had been born to one of North America's most endangered mammals. Elated researchers shined their lights around the hilly prairie dog towns of the Pitchfork Ranch in Meeteetse and reflections from ferret eyes shined back everywhere. Two different estimates that summer put the population at 128. "There were ferrets all over the place," says Kathy Fagerstone, a researcher with the U.S. Fish and Wildlife Service. "We knew there'd be high mortality over the winter, but we thought we could keep the population at a hundred."

Actually, the number of black-footed ferrets had been increasing in Wyoming ever since the population was first discovered on September 26, 1981. It was on that day, as most ferret followers already know, that Lucille and John Hogg's dog, Shep, killed an animal that got too close to its food bowl. When Lucille brought the animal—which had lovely, fine fur—to the local taxidermist to have it mounted, the taxidermist suspected they were dealing with an endangered species and called in government people.

Within a few weeks, scientists had found the Meeteetse colony, the first group of wild black-footed ferrets anyone had seen in seven years. By December, researchers from the Fish and Wildlife Service were joined by scientists working for Biota Research and Consulting, a private firm headed by Tim Clark of Idaho State University—and the first studies of the Meeteetse ferrets began.

Those studies have consisted mainly of tracking the animals to get some feeling for their movements and natural history in winter and summer, as well as keeping a close watch on their numbers. The technique Clark's group has used is spotlighting, which involves walking or driving around the 8,000 acres of prairie dog colonies and shining high-intensity lights. Black-footed ferrets are active at night, when they rummage through prairie dog burrows trying to find and kill their drowsing prey. In July, when the young ferrets first venture up to the edge of the burrows, they are fairly easy to see and count. By repeatedly checking the same spots over the course of a night, the researchers make sure they get accurate counts.

The first summer spotlight survey may not have been complete, according to Biota staff members, because nobody knew exactly how large the study area was. But field workers discovered twelve litters and counted sixty-one animals. The following summer, 1983, the count was eighteen litters and eighty-eight ferrets. During the winters following these surveys, Tim Clark and his colleagues tracked the ferrets through the snow and looked for the characteristic trenches the animals inadvertently build when excavating a prairie dog hole.

For those doing counting work, the 1984 population explosion in the Meeteetse ferrets was certainly a gratifying event. One fieldworker, Brent Houston, personally spotted more than eighty animals. There didn't seem to be a better chance to get a captive breeding program started, and it was about this time that Clark and others began prodding Wyoming's Game and Fish Department to pull some animals out of northern Wyoming. You can't really talk about the recovery of a species unless you have at least a few populations, they argued. With the Meeteetse population at a peak, a number of animals would certainly be lost over the winter. Why not take some into captivity?

A meeting had been held in April—before anybody knew that the ferret population would boom—to discuss captive breeding. Wyoming Game and Fish employees professed interest in a program, but nothing happened during the warm weather. And so the arguments were repeated, this time more emphatically, at a ferret workshop held in Laramie in September. Conservation groups, such as the World Wildlife Fund and the New York Zoological Society, both of which have funded Biota, offered to help raise money if Wyoming would produce a plan. "They

were out there in the parking lot until two in the morning talking about it," recalls one person who attended the conference. "There was some fist pounding going on." But that was the last anyone heard about captive breeding that year.

Wyoming officials say that they have never been against captive breeding as a way to enhance wild populations. They simply resented the pressure that they were getting. "We were being stampeded," says Harry Harju. "The pressure was on and we weren't going to be pushed into it." Harju and other state officials offer a variety of reasons for not pursuing the idea that year. They didn't feel that the ferrets were in any imminent danger; besides, institutions, such as the National Zoological Park, that offered to take ferrets were not capable of managing a large captive breeding program for these animals. "They could have taken them and held them but that's just a waste of everyone's effort," says Bill Morris, the chief of the Wyoming Game and Fish Department. Adds Harju: "No one, but no one, suggested taking ferrets for nonselfish reasons. If you really look at it, they all had selfish motives. That's the nature of human beings."

In fact, it may have been the state of Wyoming that was being selfish. For, as officials acknowledge, they never seriously considered allowing ferrets to leave the state. "We'd have no control over them," Harju says. Instead, Wyoming wanted to build its own captive breeding facility, and at the time there was no money to do so. "We were told by some of these institutions, such as the zoo, that if we did it, there'd be no problem with money," says Harju. "Then when we said we'd do it in Wyoming, their response was, 'No, naw, we're not interested in that.' "

To Harju and other Wyoming managers, the prospect of pulling together a complex, controlled breeding program for black-footed ferrets in less than a year may have seemed overly ambitious or even impossible. Wyoming is a conservative, fiercely independent state whose public officials are certainly not quicker than other bureaucrats to introduce change. They didn't believe captive breed-

A black-footed ferret peers out from a burrow. This species was thought to be extinct until the Meeteetse, Wyoming, population was discovered in 1981. Now it, too, is threatened.
Tim W. Clark

ing was an urgent matter—even though their own wildlife veterinarian, Tom Thorne, had warned them from the beginning that canine distemper could devastate the Meeteetse ferrets. At any rate, they were willing to take a slight gamble, which they just happened to lose. This outcome raises yet another question—whether local people, who may not see that sending some ferrets to Virginia may be far superior to letting them die in Wyoming, should be running endangered species programs.

"It was a missed opportunity," says Max Schroeder, the ferret coordinator of the Fish and Wildlife Service. Tim Clark is more harsh. "We shouldn't be in this situation," he says. "We had a biologically viable situation that we didn't capitalize on. If we had taken some animals out, we would know now if we can breed them. Assuming they did breed, we'd have forty or fifty ferrets in captivity, and we could afford to gamble a little bit. . . .If this animal goes extinct, it will be because of human incompetence."

This is strong talk, but it's not uncommon in the small community of ferret researchers and managers working out of Colorado, Wyoming, and Montana these days. A kind of bitterness has crept into relations between some of the groups, particularly between the state of Wyoming and Biota. Wyoming spent about $75,000 of its own funds on the ferret project last year, but very little of that went for primary research. Biota got grants from conservation groups and other out-of-state sources. This has put the state of Wyoming in the awkward position of getting most of its information on the black-footed ferret from people it doesn't supervise and can barely control. Most of the state's antipathy is directed at Tim Clark.

"My problem with Tim is that he makes hundred dollar statements based on ten cents worth of data," says Harry Harju. "And Tim gives nobody but Tim Clark credit for doing anything." Harju is referring partly to Clark's publicizing some of his research findings without first getting state approval. At one point, the World Wildlife Fund wrote angrily to the Wyoming Game and Fish Department, demanding an explanation of their policies on the black-footed ferret. "Their [Biota's] field people are top-notch," says Harju. "But if you spend all your time putting out brush fires, I'm not sure it's worth it."

Part of the problem here may be the West's longstanding resentment of East Coast conservationists who, westerners believe, have no practical knowledge of the land or wildlife management. Clark admits that he did some maneuvering along the way, but feels he was forced into doing so because of Wyoming's passive approach to ferret management. "They don't understand our role in the program," Clark says. "They see us solely as a technical adjunct. But we can't be constrained by their limitations. Our goal has been to force them to make some decisions, even if that means taking an adversarial stance . . . .We will do whatever it takes to get to ferret recovery."

The first sign that something was going wrong at Meeteetse came last June. Sonya Ubico, a graduate student at Colorado State University, began a routine study of diseases in the prairie dog towns there. Of seven samples of fleas she sent to the Center for Disease Control, five tested positive for plague. It was too early to tell how the animals were being affected, but as Kathy Fagerstone wrote in a memo in late June, "the situation could become very serious in the near future."

Steve Forrest, one of Biota's senior researchers, drove to Meeteetse that month. "I just went to check it out," he recalls. "I was standing out there by a prairie dog hole and this prairie dog literally comes out of its hole, spasms, and dies in front of me." Forrest, shaken by the experience,

started looking for ferrets. He walked around with a spotlight for three consecutive nights and didn't see a thing.

It was at about this time, in early July, that all the ferret people realized they had a serious emergency on their hands. In a major effort to kill the fleas carrying plague, Dave Belitsky, the state coordinator for the ferret program, gave the order to dust the prairie dog burrows with carbaryl. Since there are more than 100,000 burrows at Meeteetse, this job went on for much of the summer. At any one time, as many as six people were doing this work. Nonetheless plague spread through more than 20 percent of the prairie dog colonies at the Meeteetse ferret site, killing many prairie dogs.

Simultaneously, Biota researchers and the Fish and Wildlife Service had begun a major spotlighting effort, to get their first census of the ferrets for the new year. These counts showed severe losses, up to 89 percent in one spot known as West Core. The total population estimate was 58 animals. If the number of prairie dogs had been stable, this decline (from 128 animals the previous year) would not have been considered alarming. But, as Biota wrote to Harry Harju in August, "A small ferret population living on an eroding prairie dog base is more vulnerable to extinction than ever before." The research group again urged Wyoming and the Fish and Wildlife Service to look into the causes of the decline and to remove ferrets from the wild while there was still time.

The following month, Wyoming finally acted, pulling the first two ferrets out of Meeteetse and promising that four more would be taken shortly. Simultaneously, Clark's staff and Fish and Wildlife Service biologists began a second census of the black-footed ferrets. This time they used a mark–recapture technique, in which ferrets were captured, marked, released, and recaptured a month later. The ratio of marked to unmarked animals in the recaptured group became the basis for a population estimate. In October, researchers received the results of the second count, and they were horrified. They now estimated that only thirty-one ferrets were living at Meeteetse. What this meant was that they were continuing to lose ferrets at a time of year when the population should have been stable.

For the next two weeks, all the players involved in what had quietly become a black-footed ferret crisis argued fiercely over the meaning of the new numbers. When Harry Harju officially received a copy of the mark–capture report, he immediately scheduled a meeting for October 22. Meanwhile, another drama was starting to take shape at Sybille, the state research station where six ferrets were being held in captivity. One of the mature male ferrets had developed a slight reddening on the top of its head and had become listless. Tom Thorne, the wildlife veterinarian, thought the animal might have scabies and began treating it with antibiotics. A few days later, an NBC television crew visited the station and filmed the animal, which had suddenly become more active—burrowing and scratching around the cage. Thorne remembers thinking, "Good, he's feeling better." In fact, as Thorne knows now, the animal's condition was worsening. By that Sunday, the ferret was unresponsive, dehydrated, and refusing food. When Thorne returned on Monday evening, the animal was dead of canine distemper.

A couple of days after the Cheyenne meeting, Tim Clark and Brent Houston returned to Meeteetse for one final trapping expedition. The state had told the Biota people not to come immediately, but they came anyway. Clark, usually an intense but cheerful man, was grumpy and in a grieving sort of mood. During the time that had elapsed, state officials had enlarged the area in which no trapping was permitted, and the Biota staff's mood had

The future of the black-footed ferret may depend upon the capture, captive breeding, and reintroduction of the few remaining wild animals and their offspring.
Franz J. Camenzind

changed from shock to outrage. Steve Forrest was furious that animals with a good chance of being exposed to distemper were being left out of the evacuation program. "It's absurd," he said. "We're going to lose the whole ball game if they're going to play it that way. The point is, the entire complex of prairie dog towns is all related. A lot of mixing of ferrets goes on. The extinction rate on those very small, peripheral colonies is very high. They [state officials] are living in a dream world if they think those animals have a good chance to survive."

Clark and Houston met Dave Belitsky at the Pitchfork Ranch that night and the two groups divided up spotlighting duties. Clark and Houston saw no black-footed ferrets at all the first night. Belitsky saw one, but wasn't able to trap it. On the second night, Belitsky caught his ferret. Clark and Houston also caught one and saw a second one. They might have caught the second ferret, but the state of Wyoming didn't have enough cages ready for the ferrets yet, so they had to let it go. Brent Houston caught that ferret, an adult female, two days later. By the end of the first week the trappers had caught a total of six black-footed ferrets and the state called a halt to the operation.

Lucille Hogg, the woman who had found the first ferret at Meeteetse four years earlier, was appalled and told everybody so. "I wish I had never said anything about it," she said. "I feel guilty, like I caused this. Maybe if I'd never said anything, those animals would be okay."

Other people were thinking the same thing; a painful, but unavoidable, conclusion was that people had somehow carried distemper to the black-footed ferrets of Meeteetse—either last summer when the area was being treated for plague or perhaps even before that. "A lot of people will say, 'We knew when you found those animals you were gonna kill them,' says one state official. 'You should have just left them alone.' "

As of early December 1985, eight ferrets remained in captivity. Two had contracted canine distemper and were expected to die. Six were healthy and nearing the end of the canine distemper incubation period.—*L.R.*

But such negativism may be unfair; animals such as coyotes or raccoons could have brought in the distemper. In any case, the overwhelming cause of the disappearance of the ferrets has been that ranchers poisoned prairie dogs for most of a century, not that scientists tried to save what few ferrets are left.

The Meeteetse population may always have been doomed, simply because of its size. According to Mark Schaffer, a population modeler with the Fish and Wildlife Service in Washington, D.C., for an animal the size of a ferret, a population of fifty or a hundred probably wouldn't be large enough to prevent inbreeding. Five hundred may be the smallest number of animals possible for a viable population.

At best, Meeteetse may only have been a nursery for the black-footed ferret, a reservoir of wild animals that might have been used to help the species get back on its feet. Over the course of this winter, we will learn whether that is still a possibility. And there is always the chance, however slim, that there are more of the animals. "I don't think we've lost the ferrets, even if we lose Meeteetse," says Harry Harju. "I'm convinced there are more ferrets here in Wyoming. We've had sightings in Medicine Bow, Lost Cabin, South Campbell County, even the east side of the Bighorn Basin. Not all of these people are seeing things."

David Weinberg is a writer and a former senior editor of Natural History.

On the Track of the Last Black-footed Ferrets

by Louise Richardson

After an hour of searching, I began to wonder whether bouncing across the Wyoming prairie in the back of an icy pickup truck on a January night wasn't slightly crazy. Suddenly we stopped, and the high-powered spotlight on the cab roof fixed its beam on a distant point, a prairie dog mound. An emerald flash bounced above the mound, then stopped, suspended in the beam of light. With binoculars I glimpsed the black mask and the face behind the emerald eyes, my first look at one of North America's rarest mammals, the black-footed ferret. This one was digging inside a prairie dog burrow—probably trying to get at the sleeping occupant—and as it brought up each new load of dirt, the ferret stared into our light, which reflected a vibrant green. After a few minutes, we left it to its nocturnal dealings among the burrows and prairie dogs, its major prey.

Early the next morning, my colleague Tim Clark and I returned to the scene and found a fine five-foot-long column of dirt trailing away from the burrow. A generous spattering of ferret tracks in the snow led to other burrows and on out of sight, mapping the ferret's activities of the night before. Over the next three years, tracks

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and diggings were just two of the ferret signs we learned to read as we explored ferret behavior.

At the time, January 1982, we were just beginning research on the only known population of black-footed ferrets in the world, which had been found earlier that fall near Meeteetse, Wyoming. One of our first goals was simply to find out how many ferrets were living at Meeteetse, and by following their tracks that first winter, we got a rough count. In March we estimated that at least twenty-two black-footed ferrets inhabited the area.

The mink-sized, predatory black-footed ferret is the North American representative of a Holarctic polecat group. Its two closest relatives are the Siberian polecat and the European ferret; the latter was once used for hunting in Europe and is now commonly domesticated and sold in the United States as a pet. Ferrets are mustelids, or musk producers, as are skunks and weasels. The Meeteetse ferret population lives along the western edge of Wyoming's Bighorn Basin, at the base of the rugged volcanic buttresses of the Absaroka Range. Where the Greybull River and its tributaries leave the mountains for the Basin, they flow between a series of long, plateaulike terraces stretching eastward. The scene is rangeland—grass and scattered low shrubs—a place where grazing bands of cattle, horses, and pronghorn antelope wander. By far the most numerous terrace residents are white-tailed prai-

Franz J. Camenzind

An adult black-footed ferret hunts its prey. The ferret's diet of prairie dogs is occasionally supplemented with mice, ground squirrels, and cottontail rabbits.

rie dogs, burrowing members of the squirrel family. A complex of prairie dog towns—two large core areas and several smaller satellite towns—provide almost 8,000 acres of ferret habitat, complete with more than 110,000 burrows. In summer, the distinctive burrow mounds are alive with prairie dogs busily foraging among the vegetation and echoing a noisy barrage of warning and territorial calls. In winter, all is quiet, seemingly abandoned, while the prairie dogs hibernate deep in their burrows.

The link between ferrets and prairie dogs contributed to the ferret's current severe endangerment. The prairie dog is not only the ferret's major prey source but also provides it with ready-made burrows

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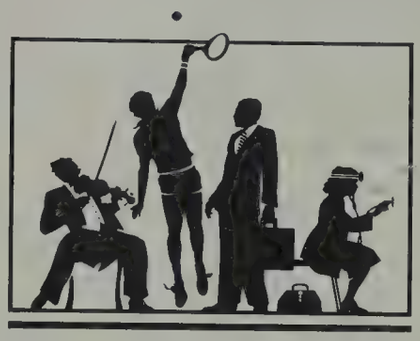

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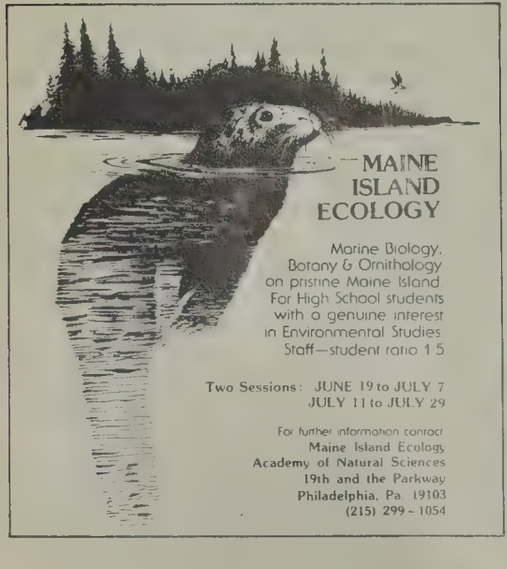

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for shelter and for rearing its litters of two to five young. Extensive prairie dog poisoning campaigns and agricultural development during the first half of this century were so effective that prairie dog numbers dropped by as much as 90 percent throughout a historical range that once stretched from Canada to Mexico and from the Rocky Mountains east to the Great Plains. Ferrets that occupied the same range also disappeared. By the 1950s and 1960s, concern over the rapidly vanishing native prairie ecosystem finally prompted some researchers to look at prairie dog reductions and their influence on ferrets. From 1964 to 1974, a handful of South Dakota researchers systematically collected natural history data on ferrets for the first time. They observed eleven ferret families during this period, but by 1974 so few ferrets were left in the wild that continuing studies became unfeasible. By 1980, no other ferret populations had been found, and many thought it time to declare the ferret extinct. Then the Meeteetse ferrets were discovered.

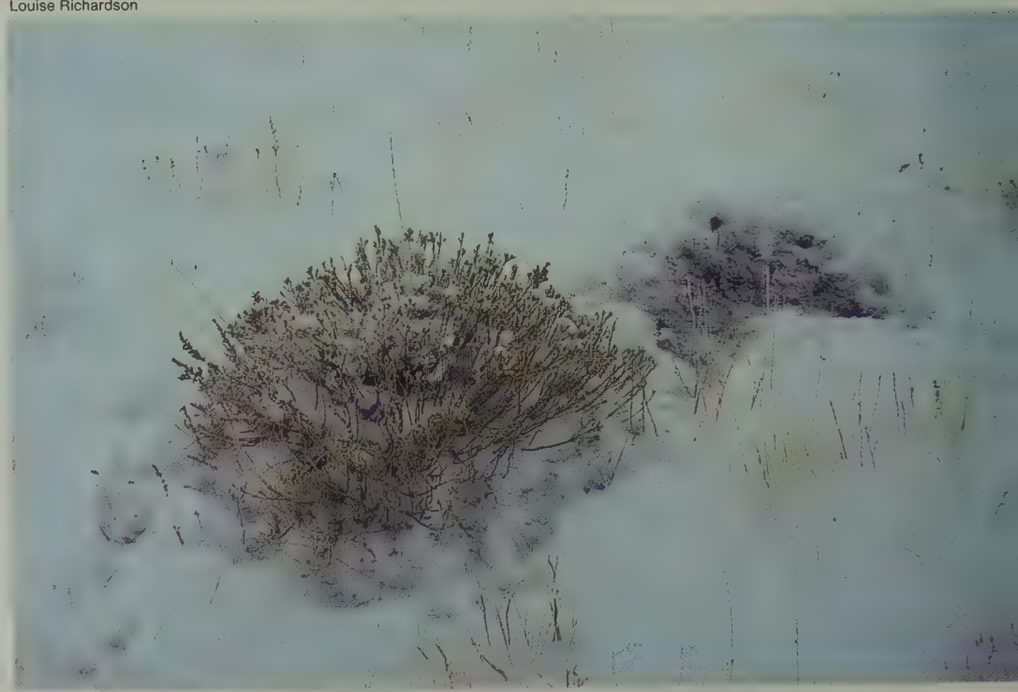
In December 1981 the only clues we had about ferret winter behavior were that ferrets were active and made some distinctive sign above ground. Because the Meeteetse ferrets were the only population known to exist, we needed to direct our research specifically toward recovering the species from the edge of extinction, while disrupting the animals as little as possible. Snow tracking proved to be an excellent study tool. It minimized disturbance of the nocturnal ferrets but illuminated their behavior. In addition, we learned about ferret habitat (essential for reestablishing ferrets in other areas) and the animal's aboveground signs (needed to refine our techniques for locating new populations).

In time, our study of information from nearly 250 ferret track routes gave our research team an enlightening, but certainly not complete, picture of ferret winter activity. Active sporadically during the cold weather, ferrets travel, on average, a mile a night. They sometimes move about above ground for several nights in a row, even at temperatures as low as −37°F, or after making a fresh kill, they may stay in one burrow for up to six nights and days.

Ferrets do not adopt a particular "den burrow." Instead, they move more or less nomadically throughout their 100-acre activity areas, a surprisingly large range for a small mammal. This knowledge helped explain why ferrets are so endangered and also made clear the extent of land required to reintroduce a ferret population. When agricultural development and poisoning campaigns whittled extensive regional prairie dog colonies to small scattered pockets, ferrets in turn were probably so dispersed among them that both their individual chances for survival and their ability to find enough other ferrets to maintain a genetically healthy population were severely reduced. Only large prairie dog complexes (several thousand acres), made up of several fairly closely spaced prairie dog colonies, can support a successful breeding population of one hundred to two hundred ferrets.

Ferrets avoid spending long periods of time above ground. Instead, they bound in zigzag fashion from burrow to burrow, stopping frequently, head out of burrow

Louise Richardson



Tracks encircle shrubs against which a black-footed ferret has rubbed its scent glands to mark territory. Except in the breeding season, ferrets are solitary.

periscope style, to peer suspiciously about. An individual may visit as many as 400 burrows a night. This behavior helps ferrets dodge a multitude of predators, including coyotes, bobcats, and great horned owls and other raptors. One morning we read the account of an attack from signs in the snow; fortunately for the ferret, the strike was unsuccessful. The ferret had just begun its foray and was fifteen feet away from its second burrow when a golden eagle hit. Amid the scuffling depressions were marks where the great bird's wing tips had pushed into the snow, probably during takeoff—tip to tip the span measured about six feet. Ferret tracks continued for another twenty feet beyond the battle zone and into another burrow. The following night the ferret was out among the burrows once again, a little bit warier, perhaps, of large descending shapes.

Because ferrets typically eat and defecate underground, enumeration of prey items was difficult. We needed to learn to what extent ferrets live off the prairie dog towns and to what extent they supplement their diet with other prey. Not until our thirty-second ferret track route did we find the curious zigzagging trough in the snow we later called a "kill drag." I followed ferret tracks to a burrow where they reemerged alongside a three- to four-inch-wide trough speckled with bloodstains and prairie dog hair. The ferret had dragged its prey to a different burrow to eat later or possibly to cache. Ferrets sometimes drag prey more than 1,000 feet (once, 4,000 feet) before finding a suitable burrow. They also follow drags made by other ferrets and rob them of their kills.

Two more winters and twenty-three kill drags later, we verified from drags, scats (feces), and several prey carcasses that prairie dogs led the ferret winter prey list. We also learned that ferrets eat carrion and so could be victims of poisoned bait. Surprisingly, three drags were cottontail rabbits (but not the larger jack rabbit), which are about the same weight as, and certainly faster than, the ferrets. Ferrets also feed on mice in winter, but apparently eat ground squirrels only in summer. Ground squirrels also hibernate in winter and make burrows in the ground. They live along the periphery of some of the Meeteetse prairie dog colonies, as well as in colonies of their own. Ferrets could probably fit into these smaller burrows, but they never used them or dug out hibernating squirrels.

Although they are solitary hunters, ferrets sometimes share parts of their activity areas with neighboring ferrets, typically when the neighbor is out of the area. We

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Tim W. Clark

A prairie dog emerges from its burrow in early spring.

expected some variation in space use between males and females, but often could not sex animals from the tracks even though males are larger than females. We did distinguish between the tracks of one large male and one small female and found that his activity area was larger than and sometimes overlapped hers.

As we learned from other studies, mustelids have evolved an interesting spatial strategy to separate animals of the same sex and to reduce conflict between individuals. Males, being polygynous, establish large territories that exclude other males and encompass the territories of one or more females. Females, however, establish smaller territories, their primary concern being food for their young, which they rear alone.

The mustelid key to maintaining spatial separation and also avoiding outright confrontation between individuals (and any injuries that may result) is scent marking. Scent signals the presence of one individual and warns away others, except during the breeding season. This is one way animals can share certain common areas of use but minimize face-to-face encounters. We suspected that ferrets scent marked, but we were not sure of just what to look

for in the snow. Urination is one form of scent marking that, along with ferret scats and the distinctive digging, has been well-described and photographed by earlier research. Mustelids as a group are also known to have well-developed anal and lateral scent glands, which they rub on the ground, shrubs, rocks, and other prominent features.

Weasels and stoats, smaller cousins of the ferret, perform two scent-marking behaviors: "anal drag," pressing pelvic scent glands against the ground while wriggling back and forth; and "body rubbing," rubbing lateral scent glands against objects. By mid-February each year, we noticed an increase in scrapings and stampings in the snow on the ground and around bushes near burrows. Until 1984, when I cautiously approached an adult male during our summer litter surveys, we could only assume that the ferrets were scent marking. As with many of the ferrets we have observed, his fear was routed by curiosity. When I came to within twenty feet, he inched toward me, sniffed, moved back to his burrow, and proceeded to wriggle his dragging posterior vigorously along the ground. Then he jumped onto a nearby bush and slithered his head and body through it, rubbing his neck, sides, and belly all over the bush. Suddenly, he was back wriggling on the ground—all in about five seconds. Here was a dynamic rendition of the two mustelid scent-marking behaviors. The ferret came close to me once more, then slowly loped off to explore other burrows. I was impressed not only by the marking display but also by the strength of the fresh odors he had deposited. There was no question as to his classification in the mustelid family.

Tracks and scent marks gave us clues to the timing of the ferret breeding season. In February and March, ferrets scent mark more often and travel much longer distances at night. Again, our hunches were supported by other mustelid research. Male mustelids typically cover much larger areas in the breeding season, and captive female black-footed ferrets held at the Patuxent Wildlife Research Center in the 1970s came into estrus during these months.

Unrelated to scent marking but particularly useful in locating ferrets is the ferret digging, which I had seen in progress that first night. Ferret diggings vary in frequency throughout the year. We easily found and marked them during the winter when prairie dogs were hibernating. But in March our recorded diggings began to disappear. A little sleuthing pointed to prairie dogs as the culprits.

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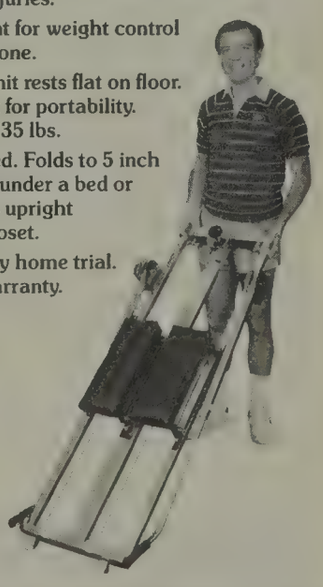

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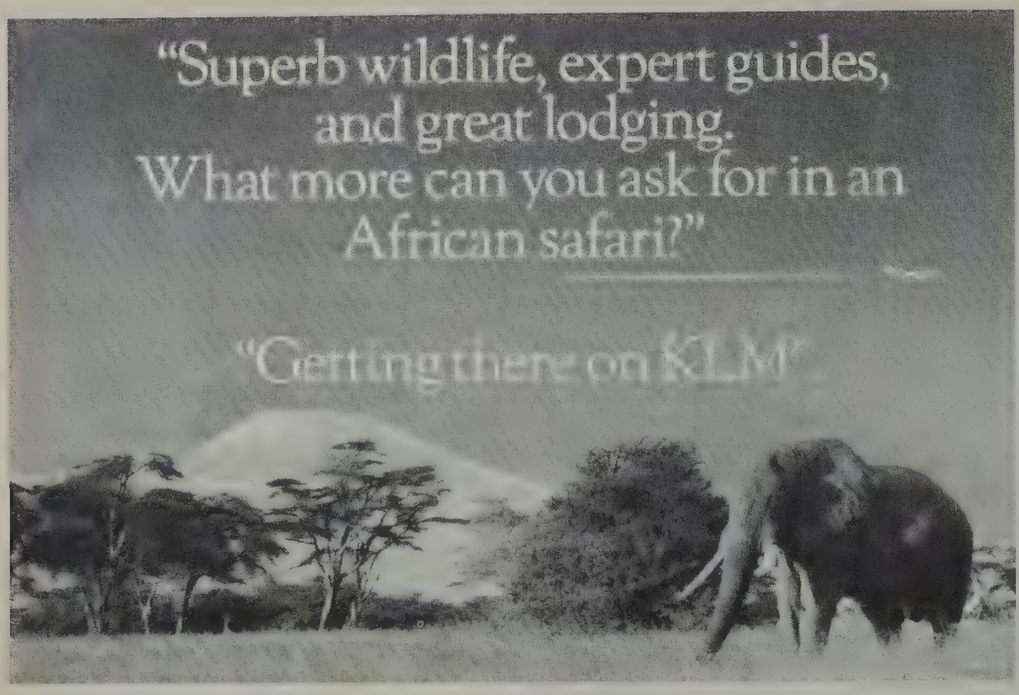

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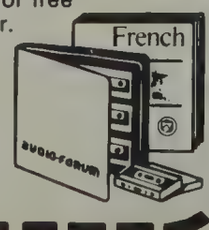

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For prairie dogs, spring signals the end of hibernation and the beginning of burrow maintenance. Old collapsed burrows are unplugged and new debris, anything lying on the ground near the burrow, is fastidiously scraped up in a circular fashion around the burrow opening. Day by day, we monitored the disappearance of ferret diggings, now part of the newly maintained burrows. Although we surveyed the study area extensively during the summer, we rarely found a recognizable ferret digging until November, when once again the prairie dogs hibernated. Summer diggings were much smaller and easily confused with diggings of other animals, including prairie dogs.

This was an important discovery because U.S. Fish and Wildlife Service guidelines for ferret searches required that prairie dog colonies be surveyed for ferret signs (diggings or the extremely rare scats or bodily remains) only between May and October. Only after searchers had found a digging, skeletal piece, or other definitive ferret sign could they spotlight at night for ferrets, a much more effective survey technique in summer because females and their litters are then very active above ground. Search techniques and guidelines are now being changed to key sign searches to winter and spotlight searches to summer. We can only speculate on how many ferrets or ferret populations might have been missed during past searches.

With the help of the U.S. Fish and Wildlife Service team, our research also included spotlight surveys from mid-July to mid-August, 1982 to 1985, the time when the litters are playing above ground as a group. This was also the only time when we could really watch ferrets, always an exciting event. Probably born in May or early June, the litters, protected and nursed by the mothers, stay below ground for about the first month of their lives. After these four weeks, the young are nearly half-grown, and the female weans them and introduces them to the world above ground and to the new burrows, sometimes forcibly dragging them about by the nape. From then until early August, the female relocates her young to new burrows every few nights and provides them with prey. Throughout August, the young play above ground at night and even during the day, staging mock battles with rough and tumble antics and exploring their outside world. Later in the month, the female begins to put the young in different burrows, the first step toward solitary adulthood. In September juveniles leave their natal areas to find and establish their own territories.

This is the time we chose for our mark–recapture work, when we trapped and marked about one-third of the population, allowed them to mix for a couple of weeks, and then trapped again. By tallying the numbers of marked and unmarked animals caught at the second trapping, we derived a population estimate. (Our best year was 1984 when the estimate was 128 ferrets.) Capturing animals marked the previous year gave us some idea of how long ferrets live in the wild (the oldest was at least three years old) and when females first breed (in their first spring). We found that some adults remain in established territories for more than a year. From 1982 to 1984, radiotelemetry studies run by the Fish and Wildlife Service research team in late summer and fall revealed that young did indeed disperse to other prairie dog towns within the complex and possibly beyond, but that in the process, a large number died from predation or possibly from wounds inflicted by prairie dogs themselves. Prairie dogs are as big as ferrets (male prairie dogs are larger by almost 2 to 1) and are certainly capable of wounding and possibly killing a ferret. High juvenile mortality is common in the mustelid family, and we learned to expect that by spring the ferret breeding population would be considerably lower than it had been the previous fall.

In the ferrets' case, unlike that of many other endangered species, habitat remains intact and reintroduction sites exist. Hopes had been high after the 1984 count that some animals could be taken into captivity to start a captive propagation program, while still leaving a large population in the wild. Captive propagation was a necessary intermediate step toward establishing new ferret populations because the wild population was so small. When animals are released to a new site, mortality is often so high that more than thirty animals are needed for release. Taking that many ferrets from Meeteetse would likely drain the population beyond recovery.

The story of the ferrets in 1985 was one of decimating diseases striking both prairie dogs and ferrets, plummeting numbers of wild animals, and capture efforts (see preceding article, page 62). Today the outlook for the ferret in the wild is grim. Only with the best of luck and good care, will the last few wild ferrets and those in captivity breed this year, thereby reviving the Meeteetse group, and eventually spawning new populations. The cold nights, the lost sleep, the recent worries will all have been worthwhile if someday anyone with an interest in wildlife can see ferrets hunting, exploring, and playing exuberantly in the wild. □

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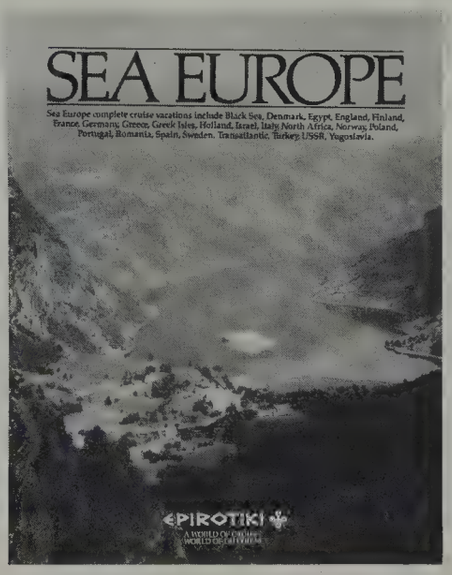

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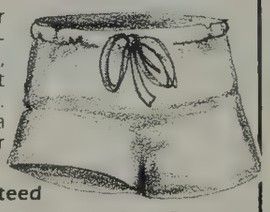

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Games Planets Play

by Thomas D. Nicholson

Venus left the morning sky in January, and this month Jupiter enters it. Saturn and Mars remain morning stars, although they switch positions, left for right, and during the last week of the month, Mercury gives us our best shot at seeing it in a long while. All the moving around, however, doesn't really improve our sky picture materially. The position and motion of Venus will keep that brightest of all the planets too close to the sun to observe for another two months. Jupiter will recover more quickly from being lost in sunlight; we should be able to see it in the morning by the end of March. Saturn and Mars provide the greatest planetary interest in February as their tortoise-and-hare tactics move Mars out in front of Saturn late in the month. This is one time the hare (Mars) wins for keeps. Even Mars's retrograde motion this coming summer doesn't help Saturn catch up. Watching Mars brighten as its July opposition from the sun approaches will also be engrossing.

A fine opportunity to view Mercury comes toward the end of the month but a clear and unobstructed western horizon will be necessary. The planet's brightness compares with the brightest of the stars (Sirius and Canopus), and it will be high enough at sundown to see before it sets.

Events in the calendar below are given in local time unless otherwise indicated.

February 1–2: This is one of those exceptional days without a moonrise even though the moon is up till after ten this morning. Last night it rose just before midnight; tonight it will rise just after. Last-quarter phase occurs at 11:41 P.M., EST, but we won't see the moon until it rises in the wee hours of the morning on the 2nd, in Libra, very near the star Zubenelgenubi. (That's a name no star gazer will ever forget!)

February 3–4: The moon repeats its performance of January with Saturn and Mars, but more quickly since the planets are now much closer to one another. On the 3rd it passes above both during a period of thirteen hours. Moonrise is about 2:00 A.M. on the morning of the 3rd. From about 4:00 A.M. on (when the moon is high enough), look close to its left for the two planets; Mars is nearer the moon. On the morning of the 4th, the planets are above the moon with Saturn closer to it. The reddish star to the moon's right is Antares, in Scorpius.

February 4: Perigee moon (nearest the earth) occurs today.

February 5–6: The waning crescent moon is low in the southwest both mornings, difficult but not impossible to see. The next opportunity for moon watching will come after the new moon.

February 8: New moon is at 7:55 P.M., EST, just before it leaves Capricornus to enter Aquarius.

February 9: Comet Halley reaches perihelion (nearest the sun) today, 54 million miles distant. This event last occurred on April 20, 1910.

February 10: Saturn requires almost thirty years to circle the sky, thus it changes its stellar position very slowly. The planet has taken a long time to pass Antares, the brightest star of Scorpius, which is near it this morning. It won't pass the star again for another thirty years. Don't confuse the star (which is below Saturn) with Mars (which is close by and to the right of Saturn). That is easy to do since both Antares and Mars are similar in brightness and in their reddish color.

February 11: Our first chance to see the young crescent moon in the evening twilight will come tonight, just as it passes below the vernal equinox.

February 14: Aries's bright stars, Hamal (the brighter) and Sheratan, can be seen above the moon tonight.

February 16: The time of first-quarter moon (at 2:55 P.M.) nearly coincides with that of apogee moon (about 5:00 P.M., EST). Almost the only effect will be a slight decrease in the range between high and low tides, usually at neap tide (when

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the quarter moons occur). The Pleiades (the tight star cluster known as the Seven Sisters) is just above the moon tonight.

February 17: Aldebaran, the reddish star of Taurus, is below the moon when it becomes visible tonight.

February 17–18: Mars caught Saturn during the night, moving below it from right to left. The two planets will appear nearest one another on the morning of the 18th and will separate slowly thereafter. Jupiter is in conjunction with the sun on the 18th, ending its sojourn as an evening star.

February 19–20: Gemini is home to the moon these nights. On the evening of the 20th, the moon is near the "twin" stars, Pollux and Castor.

February 21–22: Trace the moon's motion in orbit these nights as it moves through the dim stars of Cancer, away from Pollux and Castor, toward Leo's Regulus.

February 23: Regulus is below the moon in the early evening.

February 24: Full moon, still in Leo, is at 10:02 A.M., EST.

February 25–28: The moon moves through Virgo as it rises later nightly, waning through its gibbous phase. The star below it on the 27th is Spica.

February 28: Mercury's greatest easterly elongation today offers the best opportunity in a long while to see the planet. Evening elongations are always better in the late winter, and the planet is always brighter during an evening appearance *before* its greatest elongation (distance) from the sun occurs. With a clear westerly horizon, you should be able to see the planet during the last week of February, low in the west during the last third of the twilight period.

Editor's Note: The Sky Map in the January issue shows the evening constellations and stars for this month and gives the dates and times for use.

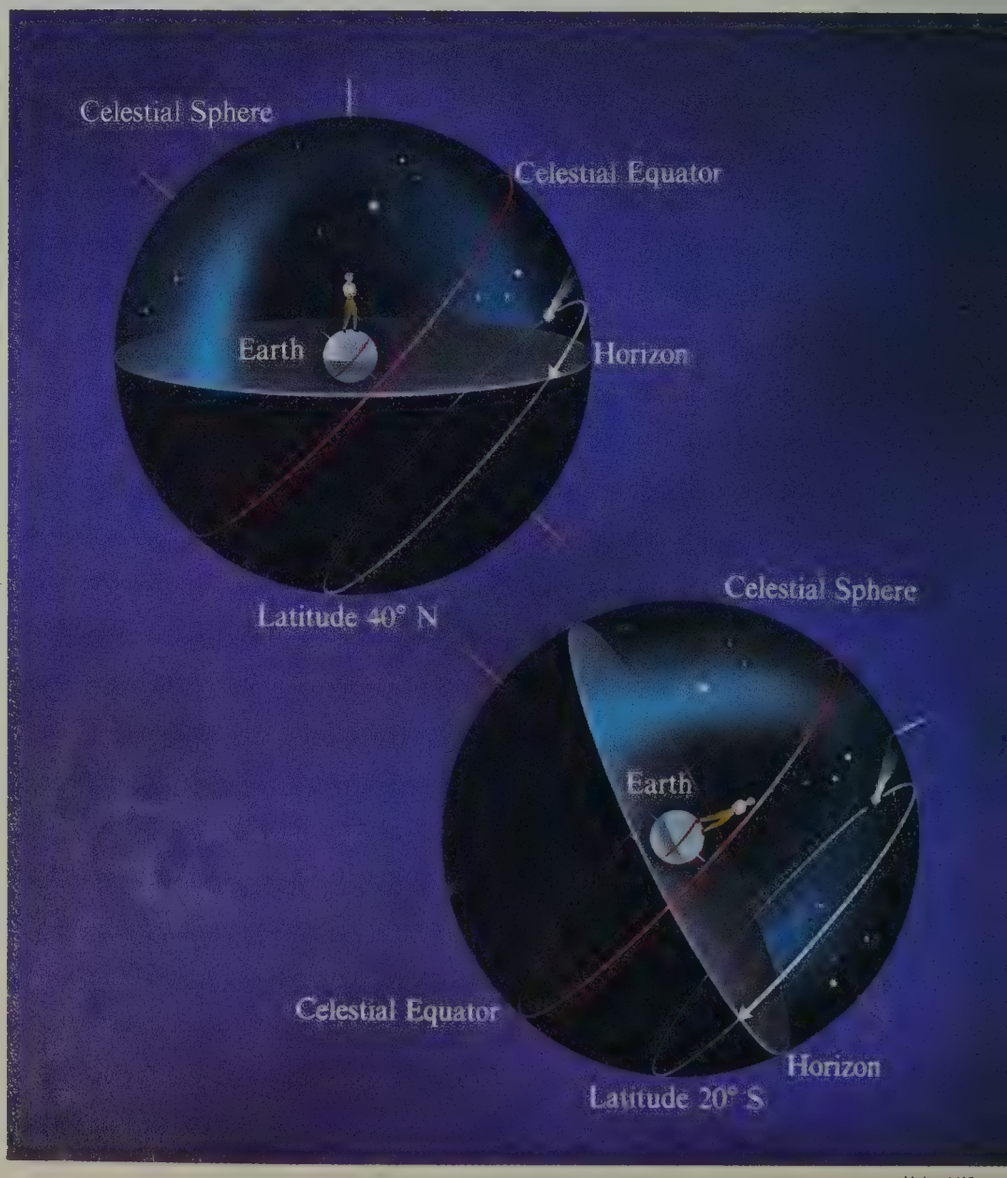
Halley's Comeback

If we could put the earth in Venus's position on February 9, when Comet Halley is nearest the sun, we would find it halfway up in our sunset sky that night, less than 25 million miles distant, at its greatest brilliance, and with an enormous tail (50 million miles or more long). Judging by 1910, the tail might stretch all the way over to our eastern horizon. Such is the view that people had of the comet during some of its past appearances.

But Earth and Venus can't change places, and we happen to be on the wrong side of the sun when Comet Halley reaches the climax of its show. Our position, virtually opposite the sun from the comet, will prevent Halley from being visible. Earth is some 93 million miles from the sun, and on February 9, Comet Halley will be about 54 million miles from the sun. Our distance from the comet that day is about 144 million miles.

This is the thirtieth appearance of Comet Halley in recorded history, and it is one of the worst in terms of viewing the comet. Ironically, however, it will also be the best from a technological point of view. Modern astronomical instruments will enable us to learn more about Comet Halley (and about comets in general) from this appearance than we did from all the others combined.

If a great flowering of cometary knowledge doesn't result from observations of Comet Halley this year, it will be very surprising. Astronomy has never been better prepared to study a comet. No other bright comet gives us seventy-six years notice of its next appearance. All the other great, spectacular comets of history have been surprises; unknown objects that unexpectedly raced in from very distant re



Helmut Wimme

The diagrams show the celestial sphere—the expanse of the heavens—with the earth at the center. On or about March 20, Halley's comet will be about twenty-five degrees south of the equator (in red). In the top illustration, an observer is pictured at about the latitude of New York City, 40 degrees north latitude. From that perspective, the comet's path (white line) will be low in the sky to the south. During the hours before sunrise, the observer will see the comet low in the southeast with its tail extending higher. As the comet climbs higher, however, it will disappear in twilight and daylight.

The bottom view (for a Southern Hemisphere observer at 20 degrees south latitude) shows the comet at the same time. Well before *daybreak, it will be above the horizon; by daybreak it will have climbed higher. The comet will not be any brighter nor will its tail be any longer, but it will be much easier to see and will be more readily visible for a longer period of time each night.*

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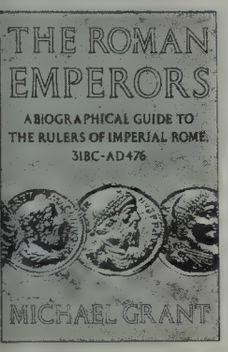

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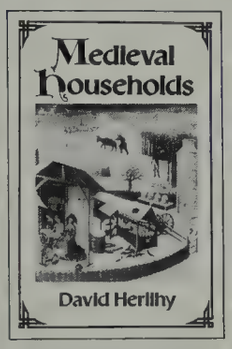

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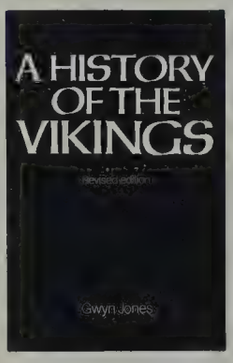

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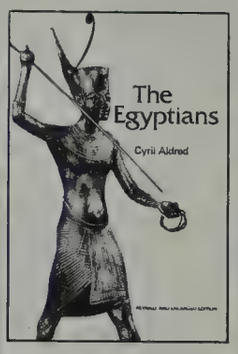

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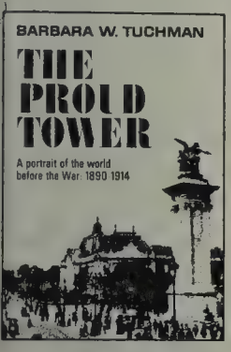

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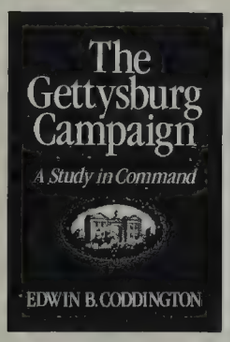

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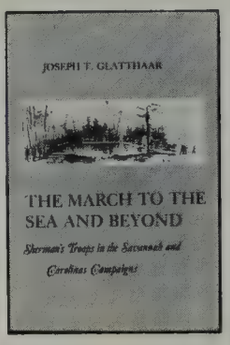

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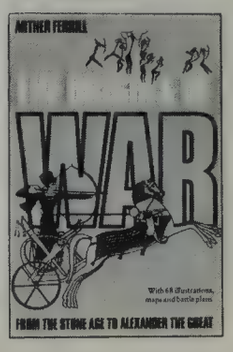

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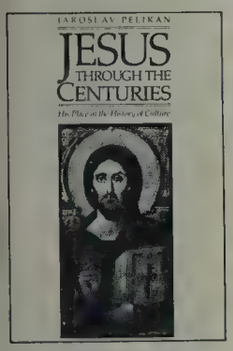

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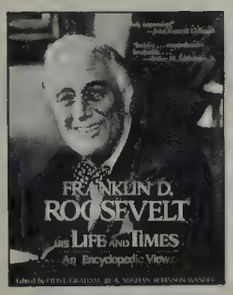

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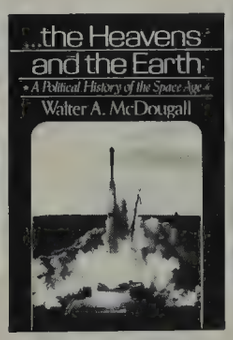

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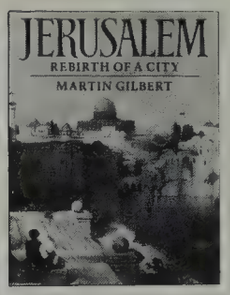

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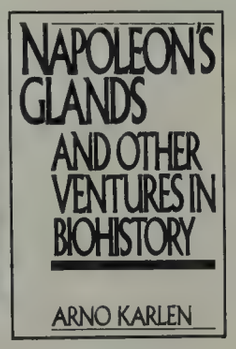

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gions of the solar system, giving us only a few months notice at best to prepare for observing them. All the other periodic comets (a hundred or so) are not very conspicuous objects; they are much smaller than Halley's comet and many have orbits that do not bring them close enough to the sun to match Halley's performance.

True, there have been other opportunities to study Comet Halley, three to be precise, since Edmund Halley predicted in the early eighteenth century that it was periodic. However, during previous appearances in 1758 and 1910, astronomers were in no way as well prepared as they are now. The principal objective in 1758 was to find out whether a comet observed in 1531, 1607, and 1682 would actually return that year. If so, that would indicate that it was indeed the same comet that periodically returns to the vicinity of the sun, as Edmund Halley predicted. We learned much more about the comet during the 1910 appearance (a particularly good one for earth viewers) from the application of photography, photometry (the measurement of brightness), and spectroscopy (the analysis of the light spectrum from an object), but those new astronomical techniques were then still in their infancy.

Astronomical instruments, methods, and techniques have come a long way since Comet Halley was first observed photographically in 1910, indeed even since the 1950s, when our modern theories of comet structure and origin were first advanced. This is the first time that the vast array of scientific, technological, and electronic apparatus developed in recent years for studying celestial bodies has been mustered to study a comet. Prior to the 1910 event, the reappearance of the comet was first confirmed in September 1909, seven months before its perihelion (April 20, 1910), on photographs taken with the 24-inch telescope of the Yerkes Observatory in Wisconsin, probably the best photographic telescope of its day. At the time of its sighting, the comet was about 10,000 times fainter than an object the human eye can see.

The first sighting during this appearance of Comet Halley, on the other hand, took place forty months before the perihelion date. It was first sighted in October 1982 with a charge-coupled device (an electronic instrument that amplifies weak sources of light) attached to the 200-inch Hale telescope at the Palomar Observatory in California. This instrument and telescope, which didn't exist in 1910, were able to record the comet's presence when it was 5,000 times fainter than at the 1910 recovery.

We may not see Comet Halley well with our own eyes in 1986, but with our modern tools of the space age we will learn what it looks like in greater detail than humans ever could before. A battery of sophisticated telescopes and imaging techniques will be turned on the object from all over the earth and from space. Four space vehicles have been launched to intercept the comet and one more to fly between it and the sun. The latter, Japan's *Sakigate,* will pass some 4.3 million miles sunward of the comet to monitor the solar wind that it encounters. Meantime, the other four will sweep past the comet in early March, about a month after it passes perihelion and becomes accessible again to earth-bound instruments.

Japan's *Planet A* spacecraft will fly past at a distance of 120,000 miles to sample magnetic fields, gas clouds, and the effects of the solar wind on the outer regions of Halley's coma (its gas cloud) and its inner tail. The other three space vehicles will have equipment designed to "see" the comet nucleus "close up."

Eleven European nations (which make up the European Space Agency) are responsible for *Giotto*, named for the fourteenth-century Italian painter whose image of a comet on the famous *The Adoration of the Magi* has often sparked comparison with Comet Halley. Equipped with electronic apparatus to detect and transmit images of the comet's appearance and to sample its gas, dust, and charged particles, *Giotto* will fly within 3,000 miles of the comet's nucleus. Two Soviet spacecraft, *Vega I* and *II*, will fly past at 6,000 and 4,000 miles, respectively, with missions similar to that of *Giotto.*

The United States did not plan to send a spacecraft to Halley, but American scientists have contributed to the design of instruments the space vehicles will carry and will play a vital role, through the U.S. tracking network, in monitoring the flight of the spacecraft and guiding the vehicles' approaches to the comet. The United States will also launch a special flight of the Space Shuttle carrying Astro-I, a package of instruments especially designed to observe Comet Halley from above the earth's atmosphere.

Thousands of professional and amateur astronomers will join in the Comet Halley space watch, to photograph and monitor the comet by means of a vast international network of instruments coordinated many years ago. Never before has so much effort been directed at seeing, tracking, and analyzing a single comet. And you can enjoy it all on television in the comfort of your living room!

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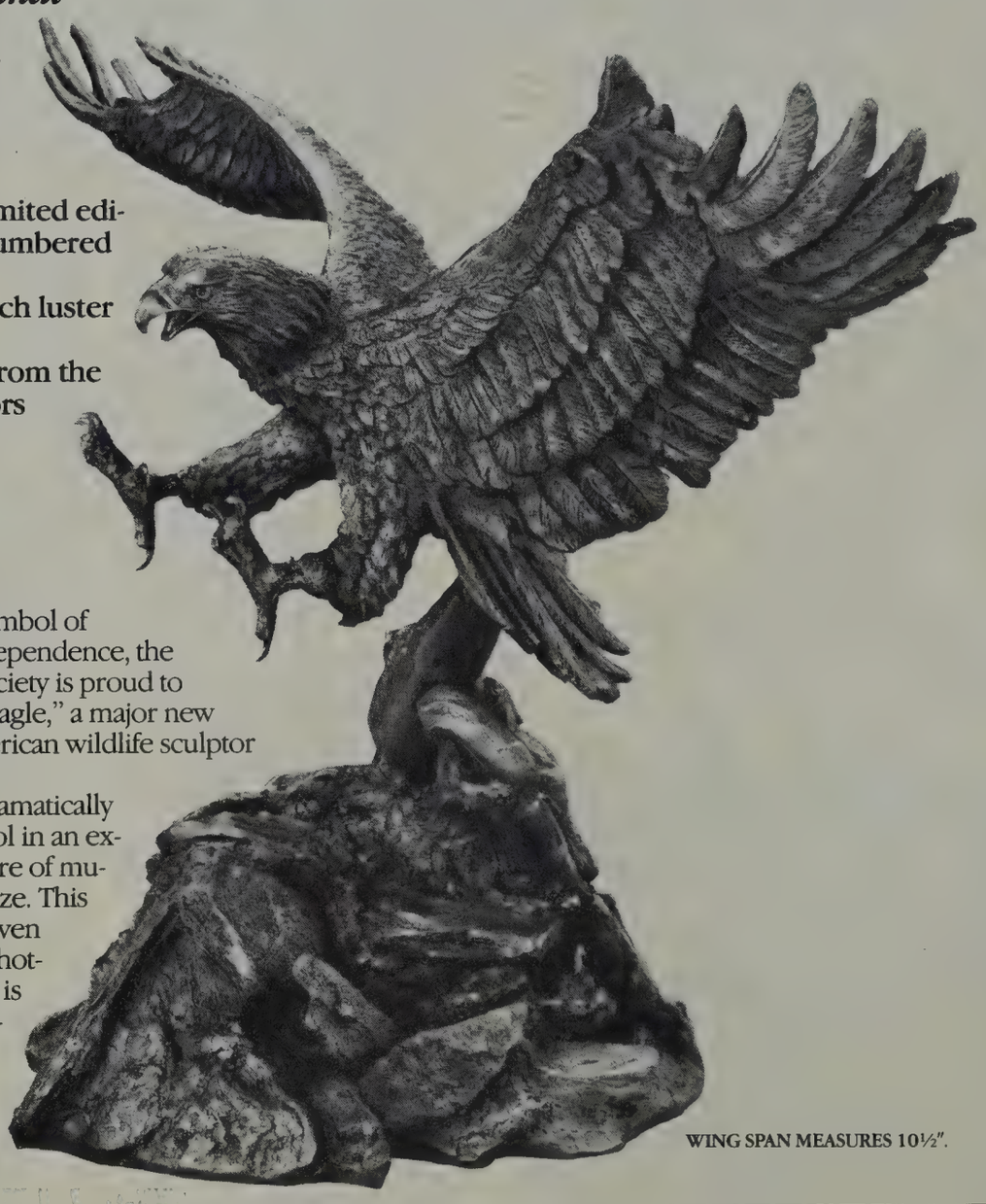

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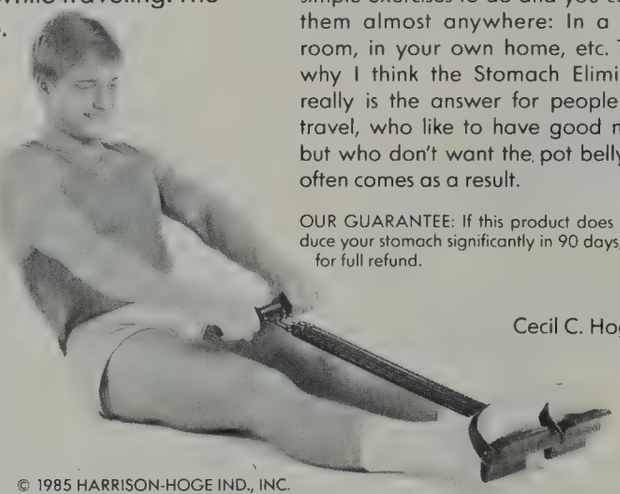

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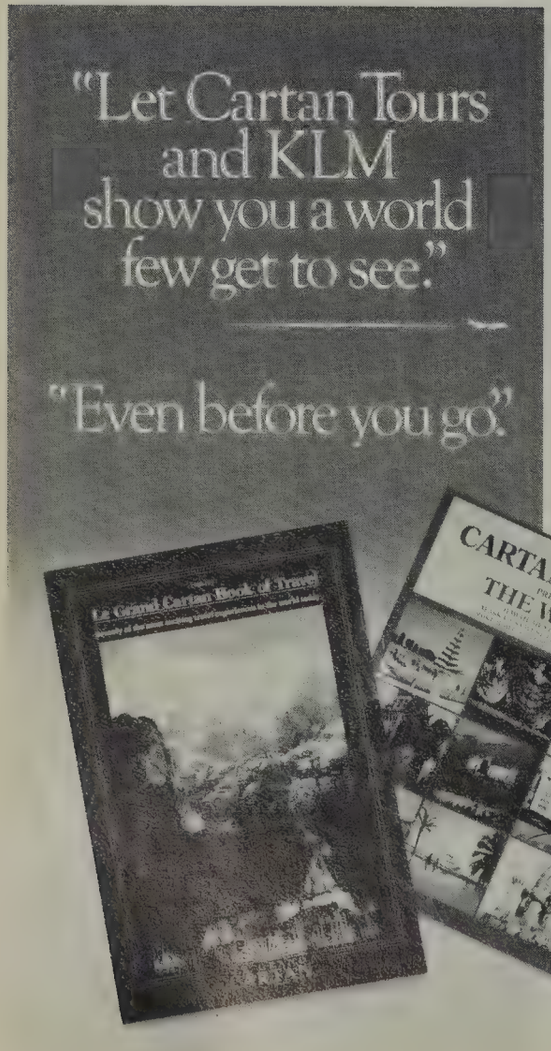
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Prime Time Science

by Jeremy Bernstein

A few years ago, inspired by a spate of television programs, such as *Cosmos* and *The Key to the Universe*, that purported to teach science to the layperson, I was impelled to formulate three laws that I felt had been violated by one or more of these science programs. I fixed on three because of Arthur C. Clarke's remark made to me when he was discussing *his* three laws. He said, "If three laws were good enough for Newton, they are good enough for me." In the best Mosaic tradition, I will restate my laws and then explain them.

1. Do Not Try to Make Things More Visual than They Are.
2. Do Not Speak More Clearly than You Think.
3. Don't Overplay Your Hand.

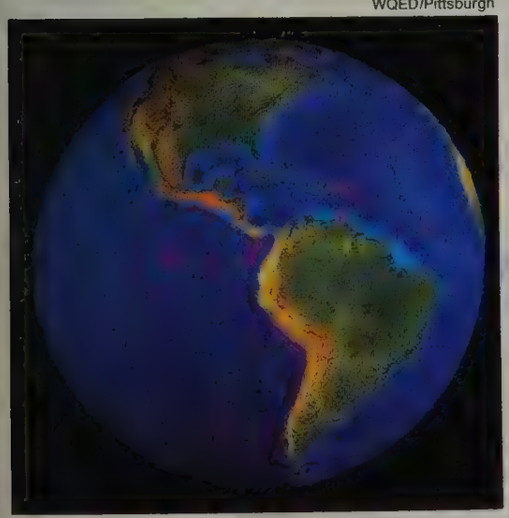
The first law was inspired by the tendency of Carl Sagan (and others) to force visualization on everything—even if it sacrificed credibility. If, for example, Kepler's mother was in danger of being burned as a witch, then we had to have the actress playing Kepler's mother looking as if she was in danger of being burned as a witch, describing her discomfit to the actor playing Kepler. No one, of course, has any idea of what Kepler or his mother or anyone else depicted in these little dramas would really say. To me this sort of thing is phony and annoying. The second law is, I must admit, a well-known saying of Niels Bohr. No one knows everything; yet the tendency of scientists and, above all, nonscientists on these programs to say, "*We* have found . . . *we* have done experiments . . . ," when in most cases all they have done is read a book or a script, is equally phony and annoying. The last law was inspired by a paragraph in Nigel Calder's

book *The Key to the Universe*, in which Calder expresses his fear that physicists would not come up with the technology he needed in time to make an exciting television program based on his book. That is just what we need, I thought, a television journalist telling scientists what to do, and when, so as to accommodate his television schedule; thus my third law.

PLANET EARTH. Produced by WQED/Pittsburgh in association with the National Academy of Sciences. To be shown nationally on the Public Broadcasting Service (PBS) beginning Wednesday, January 22, at 9 P.M. EST (check newspapers for local time).

I am pleased to report that the new science television series "Planet Earth," which premieres on PBS on Wednesday, January 22, does not violate any of these laws. The series was coproduced by WQED, Pittsburgh, and the National Academy of Sciences and features many

WQED/Pittsburgh



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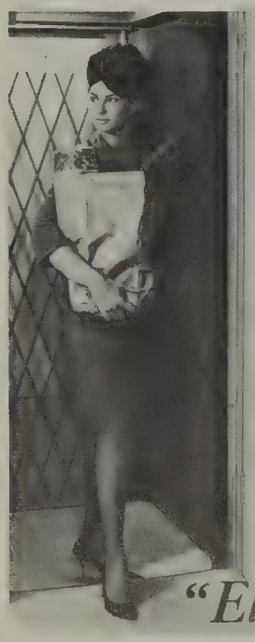

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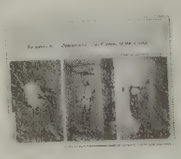

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distinguished scientists, seismologists, paleontologists, geologists, oceanographers, the odd physicist, and the like. To what end, I shall come back to in a moment. That is part of the good news. The rest of the good news is the narration by Richard Kiley and the photography. I am a sucker for Richard Kiley's voice. I believe he could read the telephone directory and make it sound interesting and convincing. What he says about auroras and volcanoes certainly sounds interesting and convincing—especially with the wonderful photography that accompanies the narration. I am also a sucker for volcanoes and auroras, to say nothing of mountains and oceans. I found the underwater photography showing that eerie stuff coming up from a site of sea-floor spreading absolutely riveting. I could watch that stuff ooze out of the earth and listen to Richard Kiley describe it all day. For many viewers this may well be all the good news they need to know.

Now for what I think is the bad news—the script. Before going into more detail, let me present for the first time to a clamoring public Bernstein's fourth law:

In Any Science Documentary Do Not Use the Following Words or Phrases: Vast, Spectacular, Giant, Incredible, Strange, Exciting, Violent, Enormous, Bizarre, Hotly Debated, Astonishing, Fantastic, and Fueling the Fires of Our Age.

If this seems too Draconian, one might soften it to read: Do Not Use Them Very Often. This law is certainly violated by the "Planet Earth"—and often. At times I thought that if I heard something described as "astonishing" or "fantastic" one more time I would become catatonic. But this is a relatively minor cavil; symptomatic perhaps, but minor. The major problem with this series is its purpose. Is it education? Sort of. It is part of a college credit course. Is it entertainment? Sort of. How many college courses are narrated by Richard Kiley? In the end it is neither. I challenge anyone who looks at "The Solar Sea," the program that deals with auroras, to define, even on the most superficial level, what an aurora *is*, based on information in this program. We are told that "charged particles called 'plasma' " impinge on the earth. This is the beginning and the end of the discussion of the concept of plasma. One gets the impression that somehow these particles, whatever they are, *are* the aurora. Nowhere is it explained that the function of the impinging particles is to excite the molecules of the atmosphere, which in turn, radiate. The real science is treated almost as an embarrassment, and one feels that the scriptwriter can hardly wait to show us an elderly Eskimo who, when the aurora comes, protects himself with a knife. That *is* interesting and it is about as scientific as the explanation of an aurora, however it probably belongs in a program about anthropology.

In these programs scientists are shown walking or riding in Jeeps on their way to dig at things. "Looks like this is going to be a good coring . . . ," one of them will say. We are supposed to believe we are in the presence of real scientific discovery. Instead, I felt that we were in the presence of some embarrassed scientists trying to sound as if they were in the presence of real scientific discovery. There are, of course, a few veteran scientific performers, like Luis Alvarez, who seem right at home describing such theories as the extinction of the dinosaurs, but they are the exception. What I am trying to say is that this program is not bad. It is just not good enough.

Maybe the situation is hopeless. Television is just the wrong medium, at least in prime time, to teach science. I think it is hopeless if it insists on behaving like television. We can't slow it down to ask questions. If only I could have asked Richard Kiley, *What* charged particles? *All* charged particles? *All* the time? *All* of them are always called "plasma?" But that wonderful disembodied voice is off and running and no one can turn back the clock. The people who produce these programs always respond to such complaints by insisting that no one would watch a program consisting of real scientists giving real lectures to real students. If they are right, then this sort of program is just another form of entertainment. And if that's what it is, then I prefer an old Bob Hope movie.

The real scientific teaching experience consists of a human, often covered in chalk dust, often secretly terrified by the sudden discovery (faced by most of us who teach) that he or she doesn't quite understand what is about to be explained. Robert Oppenheimer once said to me that he liked classes that met more than once a week. "I can correct on Wednesday the mistakes I made on Monday," he added. In a series like "Planet Earth," Wednesday goes on just as if Monday never happened. No mistakes are ever acknowledged or corrected. The pity is that it all trickles over the surface of one's mind like Muzak in an elevator.

Jeremy Bernstein is a professor of physics at the Stevens Institute of Technology and an adjunct professor at Rockefeller University. He is a frequent contributor to The New Yorker *and other publications.*

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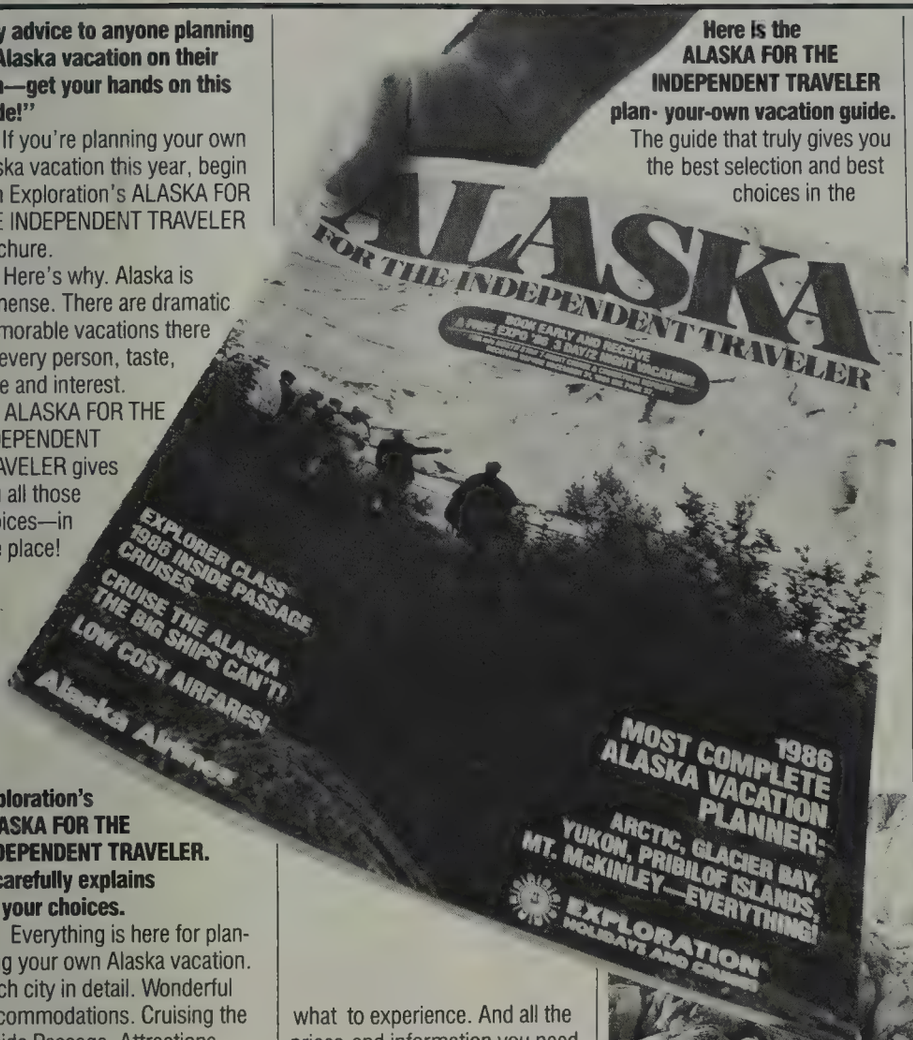

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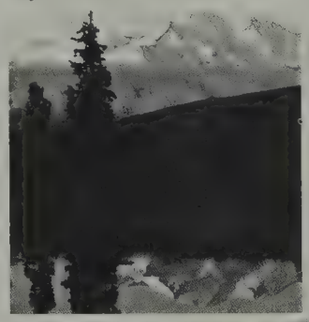

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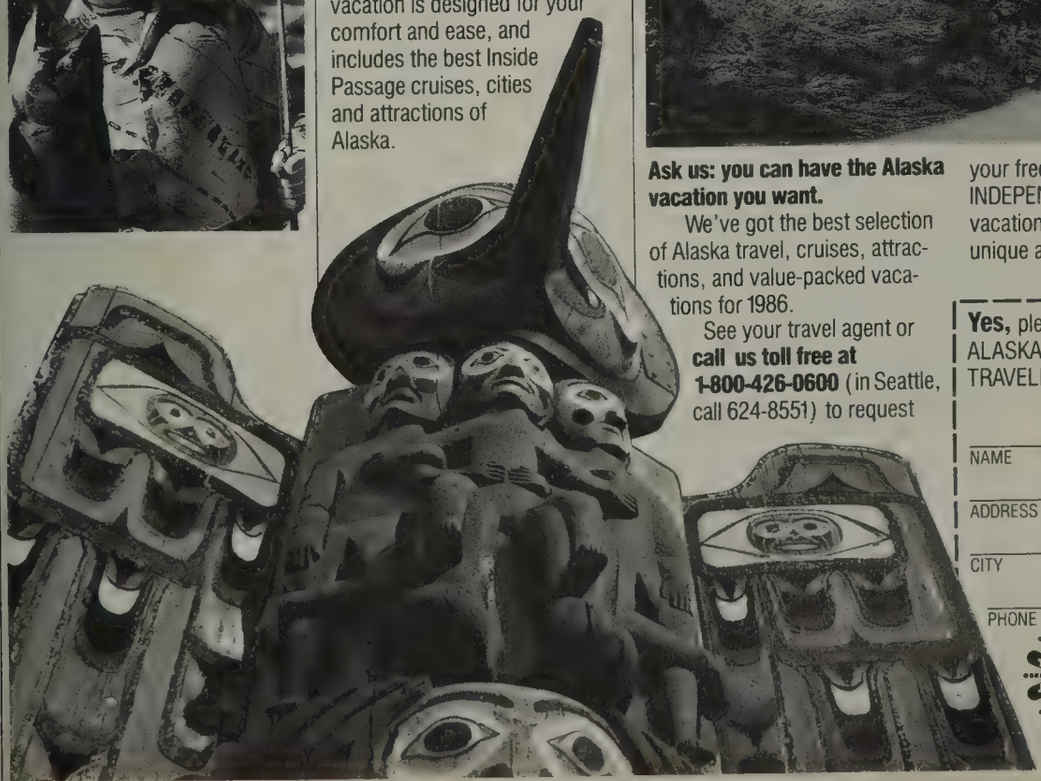

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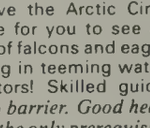

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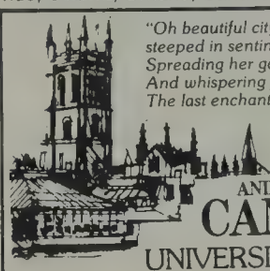

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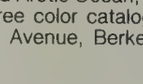

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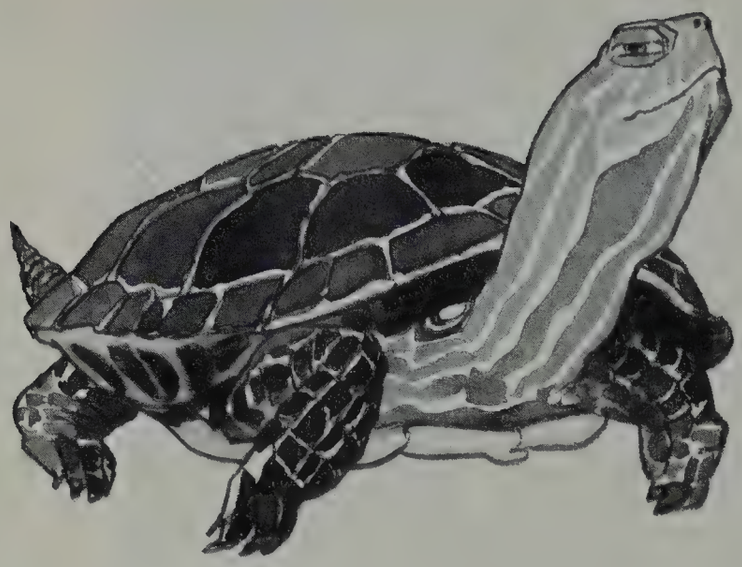

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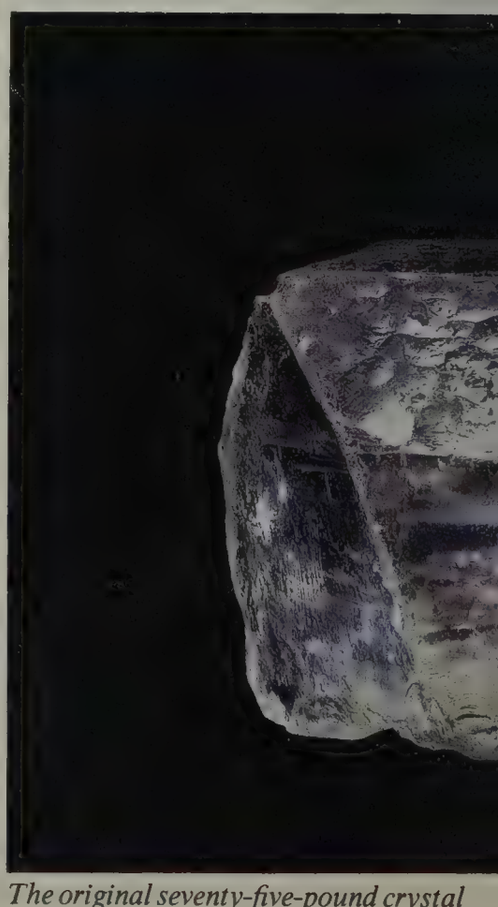
The Princess of Brazil

The Brazilian Princess, a light blue topaz, is the largest cut gem in existence. Across its face it measures five and five-eighth inches, and from the plane of its face to its pointed base, it is almost five inches deep. At 21,327 carats (about nine and one-half pounds), it is five times as big as the next largest gem in the collection of the American Museum of Natural History—a green topaz. An anonymous donor contributed the Princess to the Museum this past December, and it will be on temporary display until June.

The Brazilian Princess came to the United States in the form of a seventy-



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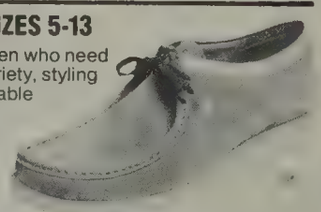

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ive-pound crystal, found in the 1960s ear Teofilo Otoni, a mountain region in astern Brazil known for its gems. (It was ne of the largest of several such crystals ound at the time.) The technology needed o cut such a large gem did not then exist, nd for more than ten years the crystal emained in storage. When a precise cut- ing method became available in the mid- 970s, gem cutters worked for more than year to create the gem.

The crystal from which the gem cutters arved the Brazilian Princess formed deep nderground in igneous rock formations known as pegmatites. As the igneous

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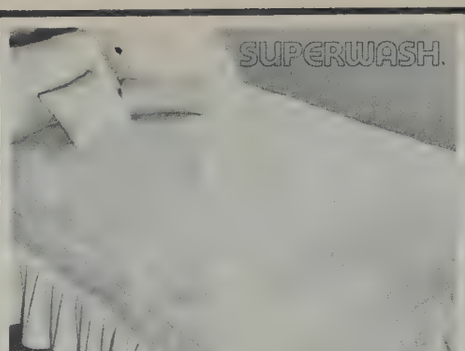

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magma cools, water, gases, and rare elements are suspended in cavities within the hardening rock. According to George Harlow, associate curator of mineral sciences at the Museum, this solution is analogous to a soup supersaturated with minerals that begin to crystalize. The liquid acts as a conductor, transporting the minerals to the growing crystal. This process takes only a matter of months, Harlow says. Topaz is often found in oversize crystals, and many of the world's larges gems have been cut from this mineral.

In addition to its size, the Brazilia Princess is remarkable in a number o other ways. It has no visible flaws, rare i any gem but particularly unusual in on this big. As Harlow explains, the large the rock the more likely that it will hav internal defects, such as cracks or bub

The Brazilian Princess topaz, shown actual size

ples. The Princess is also a dramatic example of the advances in gem cutting that have been made since the rough crystal was found. The gem's surface has 221 precisely cut facets. These large, polished planes emphasize the gem's clarity and great size. "It is an example of the lapidary art taken to extreme," Harlow says. "It gives an idea of what is possible."

Marshall Schwartzman

The Smithsonian Institution

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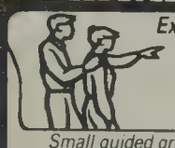

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At the American Museum

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Human Origins

At the age of six months, Richard Leakey was taken on his first anthropological expedition. He has been involved in the search for our human origins ever since. Among his well-known discoveries are a 2 million-year-old skeleton of *Homo habilis* and a 1.6 million-year-old skeleton of *Homo erectus*. On Monday, February 10, at 6:00 P.M. and 8:30 P.M. Leakey will discuss some of the many fossils he has found along the shores of Lake Turkana in the African Rift Valley and the controversies that have arisen concerning the interpretation of the fossil record. The lectures will be held in the Main Auditorium. They are $6.00 for members and $9.00 for nonmembers. Tickets must be ordered in advance. For additional information call (212) 873-1327.

Family Film Festival

In cooperation with the Museum, the Media Center for Children will present two days of children's films. This free event will be held in the Kaufmann Theater on Saturday, February 15, and Sunday, February 16; the program is the same each day. Screenings will run from 10:00 A.M. to 5:00 P.M. and will feature the following:

10:00 A.M. *Histories: Actual and Mythical*
11:00 A.M. *Transportation: Usual and Unusual*
12:45 P.M. *Animals: Stories and Documentaries*
2:15 P.M. *Folktales: From Near and Far Away*

For additional information call (212) 873-1300, ext. 559.

The Call of the Loon

To the Cree Indians, the loon was known as the Spirit of the Northern Waters. The Ojibways called it the most handsome of birds. To the Chipewyans, the loon's call was an omen of death. This large, sleek bird of the north country seems to wail, yodel, hoot, mew, and laugh. In a slide-show program on Saturday, February 22, at 11:00 A.M. and 1:00 P.M., Scott Sutcliffe will play recordings of loon calls and discuss the breeding habits and conservation of these spectacular birds. This free program will take place in the Kaufmann Theater and is open only to members. Tickets must be ordered in advance. For additional information call (212) 873-1327.

Classical Dances of India

On Wednesday, February 26, dancers Indrani and Sukyana will present four styles of Indian classical dance in the Main Auditorium. Indrani and Sukyana are the daughter and granddaughter of Ragini Devi, the famous dancer and pioneer of India's dance revival. The program will begin at 7:00 P.M. in the Main Auditorium. It is free, and seating is on a first-come, first-served basis. For additional information call (212) 873-1327, ext. 559.

At the Planetarium

The Muppets have returned to the Sky Theater to take preschoolers on a journey to explore rainbows, sunsets, and distant stars. In *Wonderful Sky,* images of Big Bird, Cookie Monster, Grover, and other favorite Sesame Street Muppets encourage children to sing along as they learn about weather and the sky. *Wonderful Sky* will take place on the first Saturday of every month through June 7. Reservations are recommended. For information call (212) 873-5714.

Courses in the Spring

The Department of Education's spring lectures, workshops, and local field trips begin in late February. Several of the many courses offered this season include *Archeology of the British Isles, Ancestors Revisited, Greek Civilization and Asia, Sex and Gender, Ethnic Communities in New York,* and *Navajo Weaving.* For a free brochure call (212) 873-7507 or write: Department of Education, American Museum of Natural History, 79th Street at Central Park West, New York, N.Y. 10024.

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- Starship: Knee Deep In The Hoopla 63659*
- Duran Duran: Rio 63452
- Oak Ridge Boys: Gt. Hits, V.2 52261
- Whitney Houston 54381*
- Linda Ronstadt: Lush Life 33200
- Billy Ocean: Suddenly 33785*
- Merle Haggard: His Best 31604
- Alabama: Closer You Get 33563
- Prince: Purple Rain 60175
- Beverly Hills Cop/Soundtrack 34379*
- Bob Seger: Night Moves 43584
- Foreigner: Agent Provocateur 70378
- Marvin Gaye: Gt. Hits 04703*
- John Denver: Gt. Hits, V.3 61664
- Crystal Gayle: Nobody 30526
- Best of Bill Cosby 12015
- The Flamingo Kid/Soundtrack 43864*
- Neil Diamond: Gold 53359
- Autograph: That's The Stuff 43271*
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- Segovia: Intimate Guitar 04628
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- Michael McDonald: No Lookin' Back 54258*
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- Dolly Parton: Gt. Hits 14090
- Urban Chipmunk 44391
- Deep Purple: Perfect Strangers 44684
- Joan Jett: Glorious Results 63731
- The Firm 20764
- Lee Greenwood: Gt. Hits 40383
- Cliburn: Favorite Piano Music 13500
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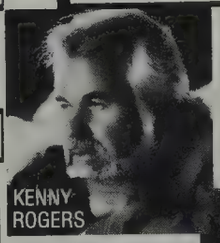

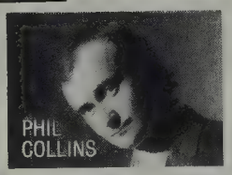

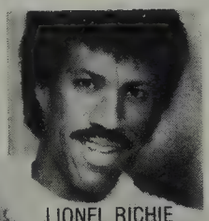
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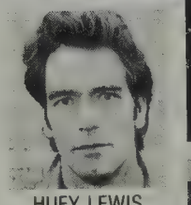
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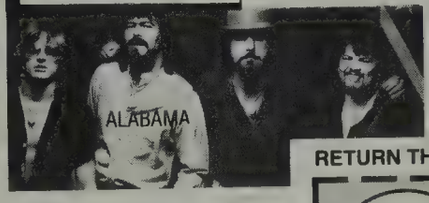

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Umbrella leaf is one of the many plants growing in Panther Creek Cove that have counterparts in eastern Asia.

John M. Hall

Panther Creek Cove, Georgia

by Robert H. Mohlenbrock

"Mixed mesophytic" forests—moist, shaded forests with a mixture of trees, mostly hardwoods—are the dominant forests in the southeastern United States. Some of the best are found in the southern Appalachian Mountains, located in steep, shaded ravines known as coves. The ample moisture and rich, fertile soil of the coves support a lush growth of trees, shrubs, wildflowers, and ferns. Recently I ventured into one of these coves on a visit to the mountains of northern Georgia, near the eastern edge of Chattahoochee National Forest. Here a picturesque mountain stream known as Panther Creek snakes its way between alternating ridges and ravines. By hiking the ridge from the summit of Black Mountain toward Panther Creek, I was able to sample the magnificent forest of Panther Creek Cove, one of several coves in the immediate area. The ravines drop off abruptly on either side of the ridge, but by clinging to the standing vegetation one can reach the cove, which is not easily accessible from other directions.

Oaks, hickories, and pines cover the dry ridge, a solid mass of green from spring until fall, when the brilliant red of the scarlet oak and the golden tones of the black oak contrast with the green needles of the yellow, table mountain, and pitch pines. In some places, a dense undergrowth of shrubby pink rhododendron and mountain laurel makes hiking difficult, but a few feet down from the ridgetop, these plants disappear as the increasing shade favors the growth of carpets of maidenhair and broad beech fern. Licorice-scented sweet cicely, blue-berried cohosh, and doll's-eyes (named for its white, glasslike fruits) poke through the fern layer in great numbers. Above the ferns and wildflowers rises an abundance of flowering dogwoods and pawpaws. High overhead, beech, tulip poplar, white basswood, sweet buckeye, red maple, and some two dozen other tree species form a canopy so dense that little sunlight penetrates to the forest floor, even at midday. Some of the trees are of exceptional size, soaring well above one hundred feet.

Here and there the forest floor is littered with the half-decayed, moss-covered

Joe LeMonnier

Panther Creek Cove

For visitor information, contact:
Forest Supervisor
Chattahoochee National Forest
601 Broad Street SE
Gainesville, Georgia 30501
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trunks of trees struck down by lightning or old age. Occasional boulders provide crevices for wildflowers such as the leathery-leaved hepatica and the dainty bishop's-cap, with its snowflake-shaped petals. Walking fern sends its slender-tipped leaves out across the rock surfaces. Deeper into Panther Creek Cove, the vegetation becomes even more lush. The maplelike leaves of the Canadian waterleaf seem to be everywhere, and at one place, an acre is solid with the arching, verdant fronds of glade fern.

On my visit to Panther Creek Cove, as I neared the foot of the ravine, just where the cove bottoms out into the flat flood plain adjacent to the creek, I came upon a vine with red-tinted flowers that I couldn't identify at first glance. It was the climbing schisandra. An uncommon vine related to magnolias, the climbing schisandra's nearest relatives live in China, Japan, and the Himalayas. It is one of many plants living in the Appalachian coves that have close relatives in eastern Asia. The red maple has a counterpart in Japan, and the sweet buckeye is closely related to a Himalayan buckeye. There are only two kinds of tulip poplars in the world, the tall, stately species of the eastern United States and a similar one in central China. Similarly, the white-flowered silverbell, a plant generally restricted to Appalachia, resembles the Macgregor's silverbell of central China.

The list of comparable species in the Appalachians and eastern Asia extends over many genera and includes magnolias, sweet gums, dogwoods, wild hydrangeas, blue cohoshes, horse sugars, May apples, and ginsengs. Ginseng, whose root is highly prized in the Orient, is a story in itself: *Natural History* readers may recall that two hundred years ago, the first American ship to trade with China sailed to the East with thirty tons of ginseng collected in the wilds of Virginia and Pennsylvania (see "Yankee Doodle Went to Canton," February 1984). The parallels between the two regions can also be described in broader terms: the trees that make up the forests are almost all deciduous, the wildflowers usually have stout rootstocks, and the forests develop on mountainsides that have dense shade and rich soils.

Ever since 1790, when the Italian botanist Luigi Castiglioni first noted the similarity between the flora of the eastern United States and that of eastern Asia, many diverse theories have been offered to explain the origin of these separated floras. Hui-Lin Li, a botanist at the University of Pennsylvania's Morris Arboretum, and one familiar with the floras of both continents, proposes that both are remnants of a great, moist forest that extended over all the Northern Hemisphere and arctic region during the Tertiary some fifty million years ago. Geological changes, including mountain upliftings, climatic variations, and glaciation, have altered the flora of many lands in the Northern Hemisphere. But the Appalachians and central China, which occupy the same latitudes, are both geologically very old, and they have remained relatively stable for the past several hundred million years.

The species of the two areas are not identical, as we would expect given their long isolation. But the visitor exploring Panther Creek Cove may pause to reflect that a similar cove, with magnolias, silverbells, tulip poplars, climbing schisandras, and May apples, exists somewhere halfway around the world.

"This Land" highlights the biological phenomena of the 153 U.S. national forests. Robert H. Mohlenbrock is distinguished professor of botany at Southern Illinois University at Carbondale.

Rob L. Jacobs

Appalachia's climbing schisandra has relatives in China, Japan, and the Himalayas.

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Water Pick

Photographer Jeff Rotman stepped off a beach on the Red Sea and almost immediately came upon a reef that looked to him like an underwater equivalent of the front porch of a general store. Tucked into the cracks and crevices of the reef were little holes, and lined up around them were queues of fish—especially moray eels—that appeared to be socializing. Rotman descended to within a couple of feet of a big moray for a closer look. The moray was perhaps six feet long and as thick as a man's thigh; its jaws appeared to be bone-crushingly strong. Morays are sharp-eyed predators that use their tubular "nostrils" to sniff out food. This one, though, was taking a break from the hunt. Around its head darted a pair of wrasse—a species of cleaner fish—which were picking worms, fungus, and the like from the moray's head, body, and gills.

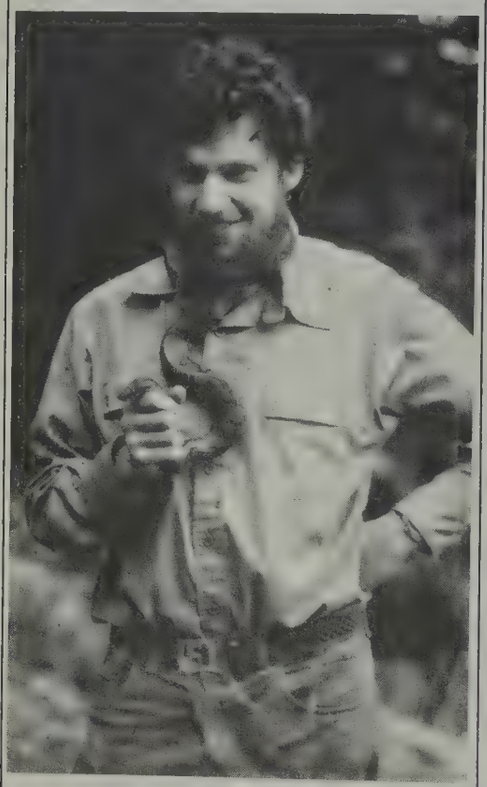
The eel remained motionless while the cleaner fish darted and nibbled next to its sharp teeth. Although Rotman knew better than to attribute human emotions to animals, he found it hard not to interpret this eel's expression as one of deep contentment. The kind of symbiosis he was watching is as close as animals can get to a free lunch. By sitting quietly while the wrasse worked, the moray got rid of a load of annoying and unhealthy parasites; the wrasse, in turn, got a hearty meal.

Morays, however, are at some risk when they take it so easy. In certain areas of the Red Sea there is a fish, known as the sabre-toothed blenny, that looks like a kissing cousin of the wrasse but preys on moray eels. An unsuspecting moray heads for a spot in a reef where it knows cleaner fish like to hang out. Settling in to be spruced up by what it assumes to be a wrasse, it may be attacked by a blenny. Chomp goes the blenny. Biting off a piece of the moray's lower lip and then rapidly swimming away, the blenny teaches the eel that nothing is really free.

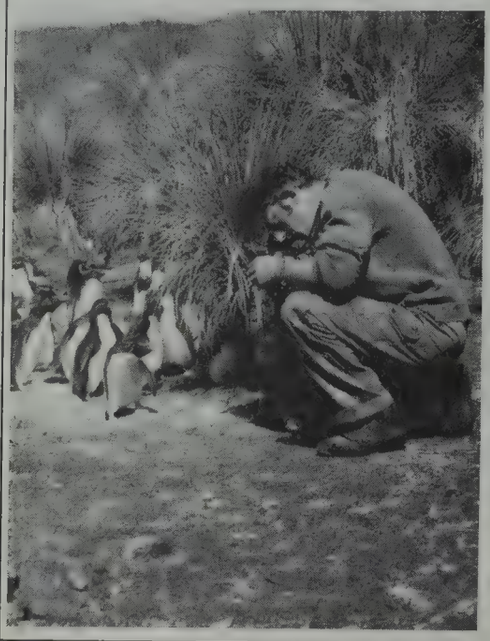
Charles C. Mann

Photograph by Jeff Rotman

When research on five monkey species in Peru's Manu National Park suggested that competition over food affected other aspects of monkey social behavior, **Charles H. Janson** (page 44), now an assistant professor in the Department of Ecology and Evolution at the State University of New York at Stony Brook, decided to explore those relationships in depth. He focused on the white-fronted and brown capuchins and found that, despite their close genetic relationship, the two differed considerably in their mating, fighting, and other interac-

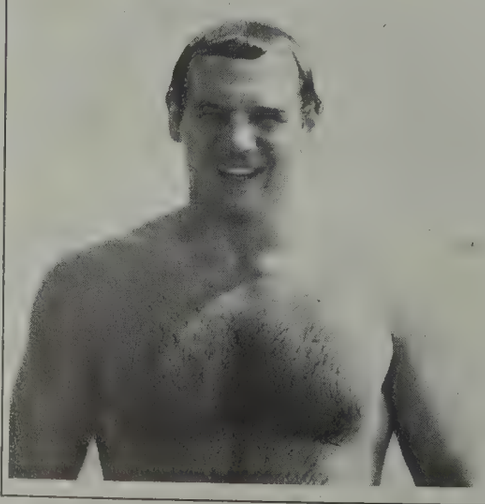


tions. When organizing and interpreting his observations, Janson drew on the comparative studies compiled in *Primate Ecology: Studies of Feeding and Ranging Behaviour in Lemurs, Monkeys, and Apes,* edited by T.H. Clutton-Brock (New York: Academic Press, 1977). Janson was also influenced by an article by Richard W. Wrangham that emphasized the importance of food-patch size in predicting the degree of cooperation between members of a primate group ("An Ecological Model of Female-Bonded Primate Groups," in *Behaviour,* vol. 75, 1980, pp. 263–99). Janson has two current research interests: the patterns of territory use by capuchins and the evolution of seed dispersal by vertebrates.



For the past twenty years, British-born **Ian Strange** (page 54) has made the Falkland Islands his home. A naturalist, conservationist, and wildlife artist, Strange is an adviser to the government of the Falklands on wildlife and environmental issues and also serves as Crown Agent Stamp Designer. The Johnny Rook first captured his attention in the mid-1960s, during a survey of remote islands in the Falklands group. His ecological study of this raptor, the first ever undertaken, has most recently been supported by an award from the National Geographic Society. Strange has written four books on the Falklands, including the richly illustrated *Penguin World* (Dodd, Mead, 1981) for adults and young adults.

The ideal ferret tracker likes camping in brisk weather (−30° F), burning the midnight oil (ferrets are nocturnal), and riding in well-ventilated vehicles (backs of pickup trucks). **Louise Richardson** (page 68) has covered a lot of northwestern Wyoming under those conditions, and she has the credentials: a master's degree from the Yale School of Forestry and Environmental Studies and experience as a teacher of mountaineering and wilderness skills. If the black-footed ferrets are rescued from extinction, much credit will be due to field scientists like Richardson who have gathered a fund of knowledge on the ferret's natural history. She is currently working on a guide to snow tracking Rocky Mountain mammals.



Jeff Rotman ("The Natural Moment," page 102) has been an underwater photographer for ten of his thirty-six years. His portrait of a moray eel, made in January 1984, was shot off the tip of the Sinai Peninsula in the Red Sea. Rotman shot the picture with a Nikon F-2A in an aluminum underwater housing, with a synchronous flash timed to 1/60 of a second. Despite its fearsome reputation, this eel rested peacefully while Rotman fiddled with his lens. Rotman's recent book of photographs, *Undersea Life* (Stewart, Tabori, and Chang, 1985) features his work in the Red Sea.

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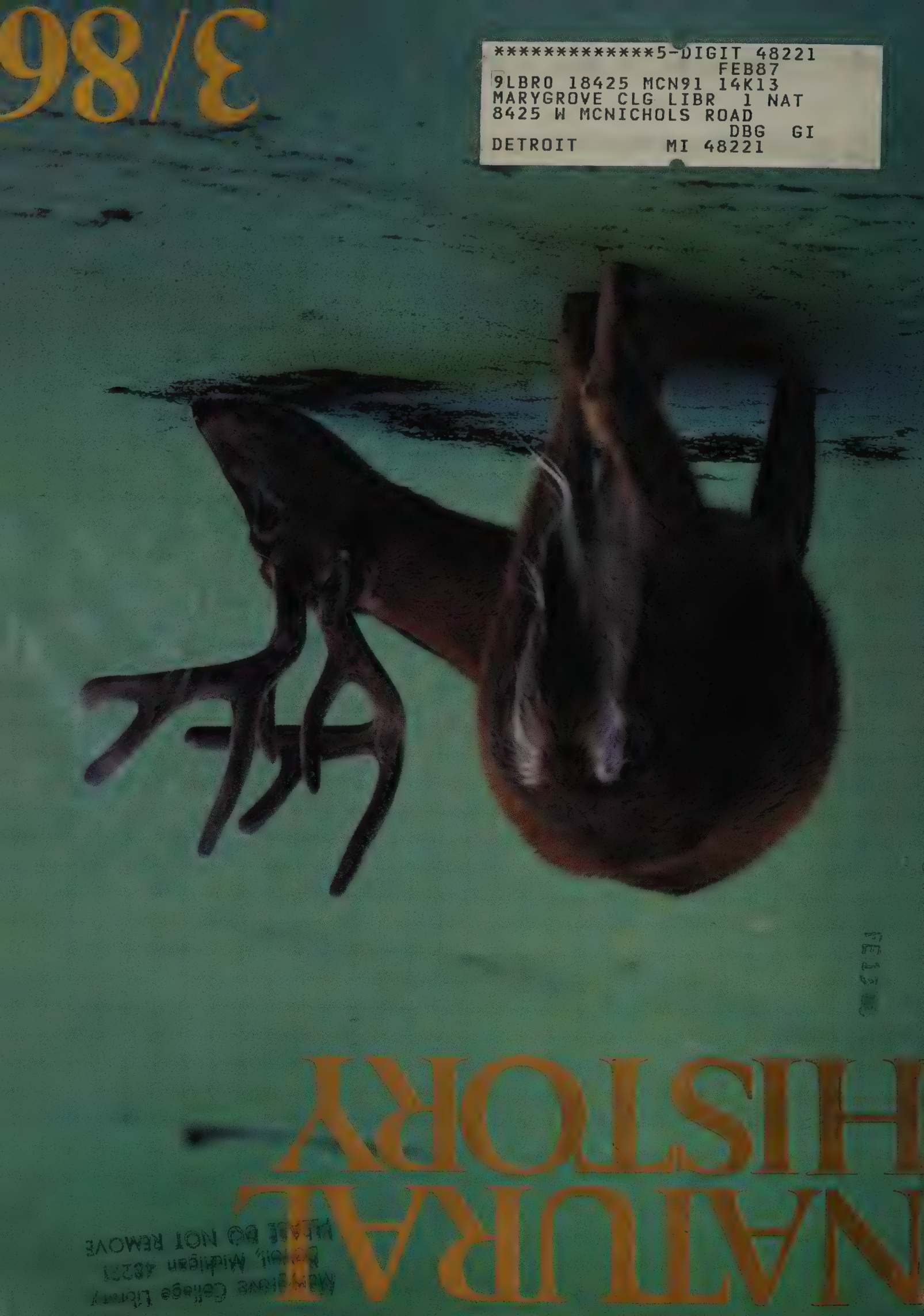

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American Museum of Natural History, New York, N.Y.
Robert G. Goelet, President
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4 Letters

6 Territory Folks *Allyn McLean Stearman*
By being "professional primitives," the Sirionó of Bolivia and their hunting culture survive.

14 This View of Life *Stephen Jay Gould*
On Rereading Edmund Halley

22 The Human Strategy *Stephen B. Vander Wall*
Gift of the Mice People

30 This Land *Robert H. Mohlenbrock*
Olympic Rain Forest, Washington

34 Fitness Fallacies *Joseph D. Wassersug and Richard J. Wassersug*
Is it smart to play with dumbbells?

38 Social Security for Birds *Scott K. Robinson*
Because they hang together, female caciques do better than males in their declining years.

48 An Ill Wind *James W. Wilson*
A dangerous form of wind shear—a cause of thirty-four airplane crashes since 1964—may catch a pilot completely unaware.

54 The Paradox of the Great Irish Stags *Valerius Geist*
Is a horny deer more swift?

66 The Bug in the Rug *Gary N. Ross*
A Mexican weaver—a "keeper of dye secrets"—reveals techniques used by the Aztecs to create brilliant red wool.

74 Reviews *Hugh H. Iltis*
Bounty of a Harsh and Meager Land

84 Sky Reporter *Stephen P. Maran*
The Jewel in the Satellite

88 Celestial Events *Thomas D. Nicholson*
Planetary Get-together

92 The Living Museum *Marshall Schwartzman*
Finds of a Lost Mission

96 A Matter of Taste *Raymond Sokolov*
The Sweet Potato Perplex

100 The Natural Moment *Photograph by Tom Eisner*
Buggy Ride

102 Authors

Cover: *A white-tailed stag feeds on duckweed in a pond near Baraboo, Wisconsin. The deer's antlers reflect his nutritional status. Article on Page 54. Photograph by Jim Brandenburg.*

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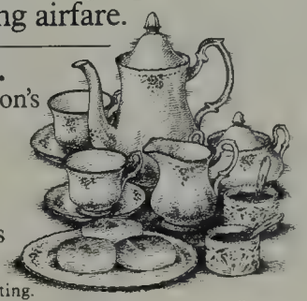

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A Marsupial Identified

Edmund Lear's painting on *Natural History*'s December 1985 cover is labeled an "unidentified marsupial." The animal is known as a Parma wallaby (*Macropus parma*), as might have been ascertained by consulting the Museum's Mammology Department. The twentieth-century name for the viverrid on pages 66–67 is *Mandinia binotata*.

MARIE A. LAWRENCE
American Museum of Natural History

Rituals of Pleasure

I would not quibble with Raymond Sokolov when, in "Tofu or Not Tofu" ("A Matter of Taste," December 1985), he defends the acknowledged wastefulness of meat consumption by pointing out that "our taste in food helps us define ourselves" and provides a ritual of familiar pleasure that is salutary. Sokolov notes correctly that reducing such waste in our own society will not necessarily translate into heightened protein production for others that happen to be on the brink of starvation.

But when he goes on to assert that "the best policy in agriculture is the one that attempts to supply people with as much of what they want as is humanly possible," he carries his point too far. One must recall that probably a number of plant and animal species are being rendered extinct in Central America right now as a direct consequence of our country's desire for whopping quantities of beef. We will never know when we might have a strong need for one of these vanishing species.

DANIEL SHIVELY
Indiana, Pennsylvania

Sokolov's most outrageous comment is that because food gives us rituals of pleasure, giving up meat would mean giving up pleasure as most people define it. Acknowledging the problems created by meat eating, he reminds us that thrift and a sensible use of the world's food resources aren't the only virtues in life. That may be so, but they certainly beat selfishness and gluttony by a long shot.

JANE CARTMILL
Encinitas, California

Crayfish: Tyrant or Prude?

Is the rusty crayfish a "Lake-Bottom Tyrant" (*Natural History,* August 1985) or a platonic vagabond? Drs. Lodge, Beckel, and Magnuson, in describing the rusty crayfish's advance through the lakes and streams of Michigan, Minnesota, Wisconsin, and Ontario, characterized the species as one that aggressively clawed its way to the top of the food chain. The authors' depiction of the devastation the rusty has wreaked is accurate, but I believe they were less than objective in their evaluation of the mechanisms responsible for the intruder's rise to ecological prominence. The authors contend that adult and juvenile rusties are more aggressive than other species of crayfish, and that this pugnacity translates into competitive superiority and, eventually, the replacement of meeker species.

This hypothesis has not been substantiated. In fact, juvenile crayfish are significantly less aggressive than adults and rarely interact antagonistically; adult aggression is more size-specific than species-specific; and any conclusions concerning the impact of aggression on competitive abilities and predator avoidance are largely speculative.

The strongest evidence to date suggests that the advance of the rusty crayfish is due to its provincial sexual preferences and its association with more "sexually liberated" species. The authors suggest that frequent matings between crayfish species may be an important factor in species replacement because such unions may produce infertile hybrid offspring. Interspecific matings do indeed lead to reduced numbers of young, but it has yet to be determined whether these offspring are infertile. Rusty crayfish do not (as the authors state) misidentify mates more often than other crayfish; they are much better than their neighbors at recognizing mates of the same species. Whereas the male rusty's predilection for female rusties results in higher relative reproductive rates, other, less discriminating species waste a large part of their reproductive allotment on unsuccessful interspecific matings. Thus, the irrepressible rusty crayfish is less a tyrant than a stalwart prude.

MARK J. BUTLER
Florida State University
Tallahassee, Florida

The author replies:

Mark Butler is correct in pointing out that there are conflicting findings regarding competition and reproductive isolation. It is not, however, clear whether the contradictory findings result from poorly designed experiments or from real differences in species, populations, or ecosystems.

We did not attempt comprehensive coverage of the interaction of *Orconectes rusticus* with all other crayfish species in all places. Butler extrapolates too readily from other sites and species to the three *Orconectes* congeners in northern Wisconsin, but he is helpful in pointing out instances where the speculative nature of our article was perhaps not adequately conveyed.

We do not intend to suggest competition is the only important factor in the replacement of congeners by *O. rusticus*. In fact, we emphasized the importance of the interaction of competition, predation, and reproductive interference.

DAVID M. LODGE

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Territory Folks

In Bolivia, Indians and ranchers maintain an uneasy alliance against farming interests

by Allyn MacLean Stearman

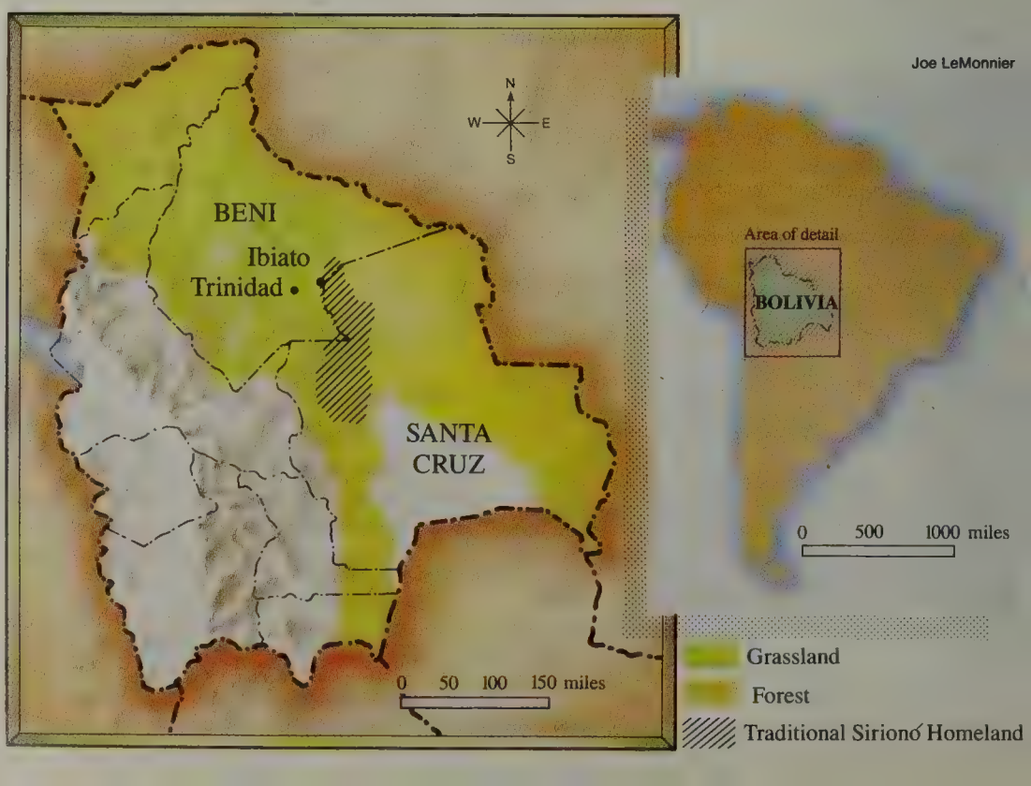
Rising out of a marsh in Bolivia's Beni Department is an old Indian burial mound. It is one of hundreds built centuries ago by the Moxos people, who at one time dominated large areas of the region. Like so many Native Americans, the Moxos gradually gave up their lands when settlers moved into their territory. Today, the mound is inhabited by the Sirionó Indians, who call their village Ibiato, "the place of high ground."

Until relatively recently, the Sirionó were nomadic, hunting and gathering in the forests to the east of Ibiato, near the Brazilian border. The 1930s brought two kinds of disruption, however: confrontations with frontiersmen trying to gain a foothold in the wilderness where the Indians hunted, and raids by a hostile indigenous group to the south, who took captive Sirionó as slaves. To protect the frontiersmen, the Bolivian military set up pacification camps where the Sirionó were to be "civilized." At the same time, both Catholics and Protestants established missions to offer the Sirionó alternatives to the excesses of the military camps. Ibiato was originally a Pentecostal mission, founded to encourage the Sirionó to become settled horticulturalists. Ironically, the expansionism that forced the Sirionó out of their homeland was not followed by a significant influx of nonindigenous people.

Well into the 1940s, small bands of Sirionó vacillated between hunting and gathering and seeking refuge at missions and camps. Ultimately, most gave up the struggle, realizing that their former way of life was no longer possible. But the safety of a sedentary existence came at no small cost. Confined in settlements, subjected to forced labor, and exposed to infectious diseases, the Sirionó perished in great numbers. Perhaps 3,000 to 5,000 Sirionó once ranged the Bolivian lowlands, but only about 500 are alive today. Many have traded their language and culture for the European customs of the national society. Against all odds, however, the 267 Sirionó of Ibiato have survived the turmoil intact. While other villages succumbed to assimilation, Ibiato alone kept its language and cultural heritage, its Sirionó flavor and life style.

The central part of the Beni Department, where Ibiato is located, consists primarily of thousands of acres of tall grass. During the rainy season, rivers and streams overflow onto the flat savanna, creating immense grass lakes. The forest, where slash-and-burn horticulture is feasible, is limited to small hammocks, or *islas* (islands), and to narrow bands running along the edges of waterways. Because of the threat of flooding and the extensive expanses of natural grass, almost all of the territory has been devoted to cattle ranching for centuries, and it remains sparsely populated.

The 15,000 or so acres of mission land the Sirionó lay claim to include both forest and pasture, neither of which they use in ways consistent with local practices. Although the Indians do not yet hold legal title to this property, their tenure at the former mission is well established and the issue of ownership is rarely raised. Rather, the ranchers and other local people complain that the Sirionó do not make "good use" of their land because they neither farm it intensively nor keep large herds of cattle. More than fifty years after exposure to horticulture, the Sirionó remain unenthusiastic farmers, each man rarely planting more than a couple of acres of rice and corn a year. Only a few of the villagers own cattle, which are usually sold or consumed before they produce off-



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The Sirionó: A Classic Case

The Sirionó Indians of lowland Bolivia were a little-known group of foragers who gained international notoriety through the anthropological work of the late Allan Holmberg. As a young graduate student at Yale University in search of a dissertation topic, Holmberg was encouraged by explorer-ethnographer Alfred Métraux to carry out fieldwork among the Sirionó Indians. In the 1930s, during one of his expeditions, Métraux spent time at a Sirionó camp and considered them to be one of the most primitive groups in South America. Holmberg's research in 1941–42 confirmed Métraux's observations: the Sirionó had no means of making fire; they had no domestic animals, not even the dog; their shelters were little more than piles of palm fronds; they did not construct watercraft; they did not work stone, bone, or hides; and they had no religious or medical specialists. The results of Holmberg's ethnographic analysis were published in 1950 by the Smithsonian Institution as *Nomads of the Long Bow,* but the book gained an even wider readership when it was reissued in 1969 in paperback by the American Museum of Natural History Press. It has again been reprinted by Waveland Press, making it one of the longest-running and most widely read ethnographic accounts in anthropology. In 1984, forty-three years after Holmberg's original research, I traveled to lowland Bolivia to determine what had become of the Sirionó.

A. MacL. S.

spring. The missionaries, who left Ibiato more than twenty years ago, encouraged the Sirionó to begin a communal herd, but because of harvesting, it has now dwindled to just a few animals. With plentiful game, the Sirionó see no reason to stockpile meat in the form of a cattle herd.

Hunting continues to provide each Sirionó family with meat an average of four days a week, and the gathering of traditional wild foods insures a variety of nutrients in the Sirionó diet. Many native peoples who give up foraging find that the change brings a marginal existence. This is true of the Trinitarios, Ignacianos, Chimanes, and other Indians who use slash-and-burn methods to grow rice, corn, plantains, and manioc in the western part of Beni Department, which contains numerous forested areas interspersed among the savannas. These indigenous groups now form part of the lowland Bolivian peasantry that subsists primarily on produce from their homesteads. Protein deficiency is common among these people because their diets include neither proper combinations of vegetable proteins nor adequate amounts of animal protein. Domestic animals such as pigs, chickens, and ducks can be found on most small farms, but since they compete with humans for food, not enough are raised to furnish consistent supplies of meat. The Sirionó, by contrast, do not suffer the dietary deficiencies that debilitate other lowland peasant groups.

Surprisingly, the hunting-based village of Ibiato has remained stable for more than fifty years. Normally, when villagers depend on wild animals for protein, they gradually exhaust the local game resources and have to move elsewhere. Studies in the Amazon area have shown that hunting-based villages remain stable for at most twenty years, usually less. Typically, hunters venture out from the settlement, taking game as it is encountered. Over the years, they must go farther and farther afield until the most expedient adjustment is simply to move the village. The Sirionó, however, have not experienced this problem. Fortuitous circumstances have allowed them to have the best of both worlds: a permanent community as well as continued hunting success.

In the western part of the Beni, many native groups have been forced to settle in a limited territory, creating competition for game resources. The Sirionó, however, are the only indigenous peasantry in their locality. Their immediate neighbors are ranchers, many of whom are absentee owners who hire overseers to take care of daily routines. A cattle ranch employs only a handful of people: the overseer (*mayordomo*), a few cowboys (*vaqueros*), and their wives, who do the cooking and washing. Tradition requires that in addition to their salary, ranch hands receive a monthly ration of such items as kerosene, flour, sugar, lard, rice, and beef. At least one cow a month is slaughtered, salted, and dried for the ranch's employees, making it unnecessary for them to hunt. Thus the Sirionó are virtually alone in their pursuit of game.

The absence of plow agriculture around Ibiato has been a major factor in the preservation of game resources. The natural pasture and the consistently high prices for beef have kept ranching more profitable than growing crops. The Beni also lacks all-weather roads, making the marketing of crops a difficult if not impossible venture. Cattle, on the other hand, can be driven to market or, as is now universal, slaughtered and the caracasses flown by small plane to market. The value of beef makes even air transport cost effective, whereas the same is not true for rice, corn, or any other agricultural product.

Since the pasture is unimproved, consisting only of native grasses that are low in nutrients, cattle density remains low. Disease, limited supervision, periodic flooding, screwworm infestations, predators, and harvesting also control herd size, preventing overgrazing or even optimal use of pastureland. At present, the Beni maintains less than a third of the 6.5 million head of cattle estimated to be its carrying capacity. Because domestic ruminants are not overgrazing the savannas, wild species such as capybara, peccary, and tapir have more than adequate forage. Swamp deer or flocks of rheas feeding beside several head of cattle are common sights.

Perhaps of greatest significance to con-

Raymond Crist

In the 1940s, Sirionó near Ibiato were just beginning to adopt clothing.

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tinued Sirionó hunting success are some major changes in technology. Dogs are now used to track game, and bows and arrows were long ago exchanged for more effective shotguns or .22-caliber rifles. While the Sirionó's access to more efficient weapons might have contributed to rapid game depletion and therefore threatened village stability, it has been offset by mounted hunting. Their relocation to an open grassland environment has given the Sirionó the unusual opportunity to use horses and riding oxen. As mounted hunters, the Sirionó have been able to extend their hunting range and diversify their strategies. Although generalized hunts, in which game was taken indiscriminately, were the rule in the past, today, both short- and long-range hunts occur simultaneously, preventing concentrated hunting in any one area.

Most older Sirionó men are not accustomed to riding and prefer to hunt on foot. Some younger men who do not own animals and must share mounts are also forced to hunt on foot occasionally. These unmounted Sirionó hunt at close range, taking smaller, more easily transported animals such as tortoises, collared peccaries, and agoutis. Those who are mounted range farther, often traveling for several days. (The oxen, with their cloven hoofs, are particularly suited to plodding through the mud.) With mounts, meat can be transported back to the village, making it unnecessary for the entire group to move to the kill site, as was the case in the past. Mounted hunters, too, are selective in the game they take; the time and energy invested in the hunt means that only larger animals will be pursued.

A bonus for the Sirionó is the opportunity to hunt in territory other than their own. While mission land more than meets their need for food crops, it would not suffice for hunting. Local ranchers still express many of the old prejudices held against Indians for generations, but they see the Sirionó as useful in maintaining a balance between wild and domestic fauna and so permit them to hunt freely on private land. For many of the ranchers, the Sirionó are their "gamekeepers," watching over the savannas on a regular basis. Some overseers depend on the Sirionó to report on conditions in remote areas of rangeland and alert them to the presence of jaguars or of sick or injured cows.

Although never a serious problem to ranchers, predators often become a nuisance. At these times many of the old prejudices about Indians work in the Sirionó's favor. In the words of anthropologist Robin Fox, they have become "professional primitives." Ranchers believe

Allyn MacLean Stearman

On the grounds of Ibiato's old mission church, Sirionó break a young ox for riding.

that the Sirionó are naturally adept at tracking and killing predators such as the jaguar and puma. When a wildcat begins killing calves, ranchers commonly seek out the Sirionó to dispose of the predator. The Sirionó's willingness to take on such hunts, which can be very dangerous, induces the ranchers to allow the Indians on their land at other times.

If the Sirionó are successful in bagging a predator such as a jaguar, they reap the additional benefit of having a valuable hide to trade. While the peasantry earns very little from crops, which are subject to wildly fluctuating prices and are expensive and difficult to transport, animal hides bring in at least a comparable income and can be transported much more easily. For example, a deer hide weighing only two to three pounds is equal in value to about ten pounds of rice or twenty-five pounds of corn. The Sirionó market their hides through itinerant traders who travel from one homestead to another, selling their wares to isolated families who only rarely make the trip to Trinidad, the capital of Beni Department. Like most other Benianos, the Sirionó keep abreast of current prices for their products by listening to radio broadcasts. When the trader arrives in Ibiato, the people already have a good idea of the value of peccary, capybara, caiman, deer, or other skins to be sold. Their ability to purchase trade goods by hunting has undoubtedly contributed to the Sirionó's reluctance to spend tedious hours in the fields.

Aside from providing meat and cash to the Sirionó, hunting also confers status, prestige, and a sense of well-being. A man who is a good hunter receives honor from his friends, neighbors, and family. He is respected as a capable provider and a person of worth. Even today, with attitudes and values from the outside world impinging on the residents of Ibiato, it is still the good hunter who receives the greatest accolades. For this reason as well, the old traditions continue.

The present equilibrium between ranchers and hunters depends on many factors, most of which are outside the control of either group. It is a fragile system that could easily be destroyed. Population pressures in Bolivia's mountain region place agricultural land at a premium. In the heavily forested eastern frontier of the Beni, just as in the western forests, expansion is beginning to take its toll on virgin wilderness. So far, ranchers in the central grassy plain have not yielded to this pressure, but should plow agriculture and the production of crops begin to take precedence over cattle, the landscape would be radically altered.

Farming would also bring in more people, who would compete with the Sirionó and ultimately kill or drive off the game animals. Under such circumstances, the Sirionó could not continue their present way of life or even prevent their land from being overrun by squatters. Their greatest hope for survival may be that, in this drama at least, the cattlemen will successfully hold off the sodbusters.

Allyn MacLean Stearman is an associate professor of anthropology at the University of Central Florida, in Orlando. Her book, No Longer Nomads: The Sirionó Revisited, *will be published this year by Hamilton Press, Lanham, Maryland.*

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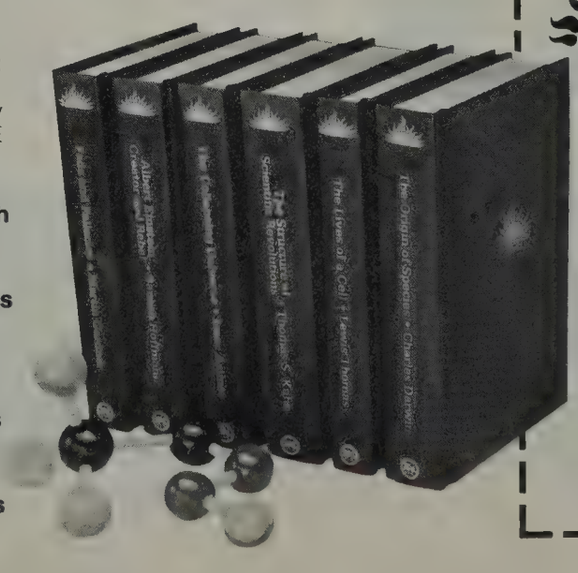

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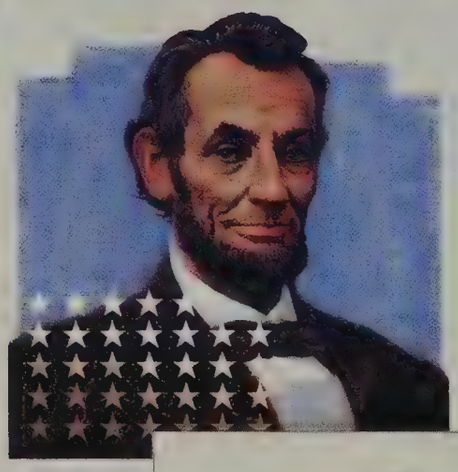

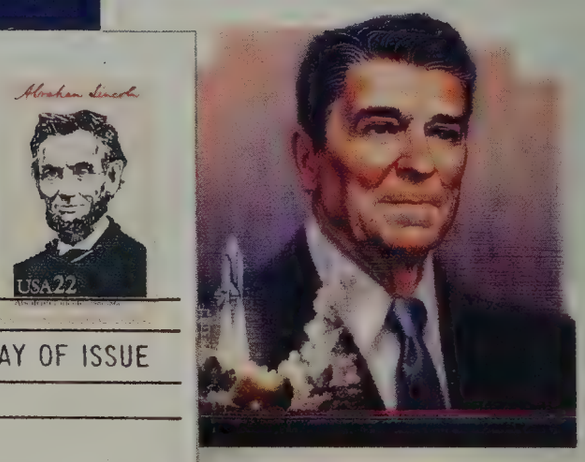

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On Rereading Edmund Halley

His argument about the earth's age was not a battle against religion

by Stephen Jay Gould

I had intended to crown my iconoclasm by ignoring Mr. Halley in this forum. Everybody else is writing more than anyone can bear to read about his nonevent of our generation. Besides, I'm mad at him. I've been waiting eagerly all my conscious life for my one chance to see that damned thing—and now we unfortunates of the bright midlatitude cities can expect no more than a dot in our best binoculars on a good night.

I was, nonetheless, drawn to this man by a curious omission or underplaying that I detected in the flood of articles written about Halley in the light (hmm!) of his namesake's return. We are all parochial at heart and tend to view wide-ranging geniuses like Halley as members of our own fraternity, even for limited contributions. I insist that Thomas Jefferson was primarily a paleontologist, and insurance salesmen surely view Charles Ives as a compatriot who occasionally dabbled in composition (as they, no doubt, appropriate Edmund Halley, who devised some of the first actuarial tables).

In my parish, Edmund Halley ranks as a geologist who occasionally looked upward. We claim him for a five-page article published in the *Philosophical Transactions of the Royal Society of London.* Its title exhausts a good part of page one: "A short account of the cause of the saltness of the ocean, and of the several lakes that emit no rivers; with a proposal by help thereof, to discover the age of the world." In short, Halley wrote one of the finest and most influential papers with a testable proposal for that *primum desideratum* of our discipline—the earth's age. Moreover, his method, though ultimately flawed, engendered much fruitful research and was, before the development of radioactive dating, among the two or three leading contenders for addressing this fundamental question.

Yet this paper and its interesting idea, so central to my profession and its history, got lost in the popular articles on Halley. *Discover* magazine abandoned its tradition of contemporaneity and named Halley their scientist of the year—but gave his geological work less than a paragraph. Carl Sagan and Ann Druyan's *Comet* awarded just a few lines more. John Noble Wilford's long article in the *New York Times* science section (October 29, 1985) omitted it entirely from a long listing of Halley's achievements.

This veil of silence forced me back to my old Xerox of Halley's original, lovingly made in my graduate student days at the American Museum of Natural History, from a beautifully bound set of this oldest scientific journal in English. I had often assigned its offspring to students but had not read the original for several years. Perhaps, if I encountered something intriguing, I might actually find a chink of difference and be able to add, rather than merely reiterate, if I chose to write about Halley after all. I plunged in and read with mounting disappointment. Nothing unremembered, nothing unusual. Oh, I did manage a tiny contribution to the great issue that seems to obsess press commentators—the spelling and pronunciation of the man's name. We have been instructed so often to say "Edmond" (not "Edmund"), that "o" has become an insider's badge of sophistication. But he is Edmund in this article (and the indifferent spelling of Halley's time probably made either quite acceptable to him). As to the other vexatious mystery—why Americans, flagrantly disregarding one of the few decent guides that English spelling offers for pronunciation, insist on calling the man "Hayley"—I can only conjecture (as many others have) that our minds were poisoned by a certain Haley (properly "Hayley" by virtue of the single "l") who made a lot of noise when I was a teen-ager and also called his group the Comets.

Reading long after midnight, I finally came to the last paragraph, having no fun at all as the clock struck one (and unable to get that wretched tune out of my head). Then I had a moment of discovery, that one instant in ten thousand that makes a scholar's life so exciting, and that justifies the enormous tedium and discipline accompanying any serious intellectual work (Edison's old allocation of effort between perspiration and inspiration is just about right—ninety-nine to one). I realized, in short, that I, and every other comment I have ever read about Halley's proposal for the earth's age, have interpreted him precisely the wrong way round. I also think I know why. The difficulty lies not with anything Halley wrote. His meaning could not have been stated more explicitly. Rather, for concerns of our own, and by a traditional misreading of the history of science, we have simply passed over Halley's own construction and imposed our preferences upon his reasoning. It's a damned shame, too—for his intent is both interesting and instructive for us today.

Halley's article makes a simple and elegant proposal. (The bare bones of the method have not been misinterpreted, only Halley's view of its meaning.) He assumes that the oceans were originally fresh and have become progressively more salty through an influx of dissolved materials transported by rivers. Since rivers flow in, but nothing flows out, salt must accumulate steadily. (Evaporation returns ocean waters to rivers in our hydrologic cycle, but evaporated waters are

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fresh and leave their salts behind.) We usually regard river water as fresh, but Halley recognized correctly that streams carry tiny (and untasteable) amounts of dissolved salts:

> But the rivers in their long passage over the earth do imbibe some of the saline particles thereof, though in so small a quantity as not to be perceived, unless in these their depositories [that is, lakes and oceans] over a long tract of time.

Halley recognized that this argument for the source of oceanic salt suffered one grave methodological defect. The world ocean is a sample of one. How can the ocean, by itself, prove the general proposition that basins with riverine inlets, but no outlets, become progressively more salty with time? Perhaps the ocean is just a special case proving nothing but its individuality, not the largest representative of a general process.

The cleverness of Halley's argument lies in his recognition that lakes, properly classified and divided, serve as smaller systems representing the same process he proposed for oceans. So he sorted large lakes into those—most of them—that have both inlets and outlets, and the few that, like the oceans, receive waters from rivers but permit no exit beyond evaporation.

He could find only four in this second category comparable with oceans—the Caspian Sea, the "Mare Mortuum" (Dead Sea), "the lake on which stands the City of Mexico," and Titicaca in Peru. All are salt to varying degrees, while all freshwater lakes fell into his first category. Halley's taxonomy of lakes had confirmed his theory for the origin of salt in oceans—a fine example of the methodological principle that sample sizes can often be increased only by recognizing proper analogues in other classes of objects.

Halley now felt ready to advance his argument for the age of the earth (or at least for its oceans):

> Now if this be the true reason of the saltness of these lakes, 'tis not improbable but that the ocean it self is become salt from the same cause, and we are thereby furnished with an argument for estimating the duration of all things, from an observation of the increment of saltness in their waters.

If we could measure the salinity of modern oceans, then determine the amount of salt brought in by rivers each year, we could extrapolate back to an initial time of no salt at all and estimate the age of the oceans. Halley recognized that his method required a set of simplifying assumptions that might not be strictly true—rough constancy of annual influx, no appreciable loss of salt in buried sediments, for example. But he felt that his method might give a reasonable first-order estimate.

Halley, who had such a keen sense of what was doable and what merely thinkable, realized that he could not hope to measure the annual influx accurately—too much variation among too many rivers and probably too small a total compared with the amount of salt now in the oceans. But we could, for the benefit of posterity, make accurate measurements of salt now in oceans and lakes; for, a few centuries hence, the total increase should be palpable enough to permit a good estimate of average annual increment. Halley advised:

> This argument can be of no use to ourselves, it requiring very great intervals of time to come to our conclusion . . . . I recommend it therefore to the Society, as opportunity shall offer, to procure the experiments to be made of the present degree of saltness of the ocean, and of as many of these lakes as can be come at, that they may stand upon record for the benefit of future ages.

The geological literature contains a "standard" interpretation of Halley's contribution. It points out, first of all and quite correctly, that Halley's method was wrong—a good try to be sure, but ultimately based on a false premise. Halley assumed that since salt entered the oceans every year, yet the sea was not saturated (as the greater salinity of the Dead Sea attested), newly entering salt must be added to the amount already present. But many of nature's cycles are maintained in dynamic balance between influxes and outflows, long before most components reach some theoretically maximal level. Our atmosphere could maintain a lot more carbon dioxide, but until we began messing with an old balance by burning massive amounts of fossil fuel, carbon dioxide had remained relatively steady at percentages much smaller than the atmosphere can hold (as we may discover to our great sorrow if current rises lead to a runaway greenhouse effect).

Most components of the atmosphere and ocean are in such dynamic balance on our ancient earth. (In a sense, they almost have to be, for the earth is so old that any directional increment, however small, would lead to saturation in a fraction of historical time.) Oceanic salt persists at its current level in such a dynamic balance, or steady state, between influx from rivers and numerous processes, including burial in sediments and biological uses, that constantly remove about the same amount that enters. Perhaps, right at the beginning of things, an originally fresh ocean accumulated salt in Halley's manner. But that process of initial increase ended long ago, and Halley's method cannot reach so far back into the abyss of time.

This usual presentation of Halley's crucial error is then balanced in traditional accounts by warm praise—for two main reasons. First, Halley wins kudos for making the first serious quantitative proposal to determine the earth's age. Moreover, though Halley felt that he could not apply the method himself, his suggestions were followed by later scientists, particularly toward the end of the nineteenth century by the great Irish geologist John Joly who used the accumulation of salt to propose a date of 100 million years for the earth. Although we now recognize Joly's estimate as vastly too small—the earth is some 4.5 billion years old—his work represented a great advance on previous speculative traditions that had led to little but hot air and had rarely dared to imagine dates even so old as Joly's.

Secondly, Halley has been proclaimed a hero in the false view of history that sees light and truth locked in perpetual warfare with religion. Halley does begin his article by rejecting a literal interpretation of Genesis for the earth's age. He accepts, because scripture so states, that humans have lived on earth for some 6,000 years but denies a creation of all things just five days before:

> Whereas we are there told that the formation of man was the last act of the creator, 'tis no where revealed in scripture how long the earth had existed before this last creation, nor how long those five days that proceeded it may be to be accounted; since we are elsewhere told, that in respect of the almighty a thousand years is as one day, being equally no part of eternity; nor can it well be conceived how those days should be to be understood of natural days, since they are mentioned as measures of time before the creation of the sun, which was not till the fourth day.

But Halley writes these lines as a liberal theist, not as a scientist engaged in a conscious battle with religion. The word *scientist* didn't exist in Halley's day, and close ties between rational science and sensible religion were sought by nearly all scholars engaged in work that we would now call scientific. Halley, in other words, speaks here for the liberal consensus of nonliteral interpretation.

The traditional literature usually unites these themes of praise in a single phrase: Halley ranks with the heroes of geology because his method, though flawed, does provide a *minimal* estimate of the earth's age (the time of accumulation before oceans reached steady-state). The *Discover* man-of-the-year article concludes: "His effort was useful because, in arriving

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at a minimum age for the earth, it inspired others to look for better geological clocks."

And so I have always read, and taught, Halley's argument for the earth's age—as a *minimal* estimate proposed to burst the bonds of a biblical literalism that made science impossible because ordinary causes could not produce the geological work required in but a few thousand years. And so I read it again last week—until I came to the last paragraph. Here Halley conveys one of the most important and subtle points of good scientific methodology—a lesson that ranks above all others in rules of procedure that must be purveyed to advanced students beginning their own careers in independent research.

In complex historical sciences like geology, few situations can be as well controlled as ideal laboratory experiments. Biases are unavoidably and intrinsically contained within available data. Since these biases cannot always be removed, researchers must follow one cardinal rule—they must be sure that recognized biases lie in a direction that will make confirmation of their hypothesis *less* likely (for if sources of bias tend to support favored views, how can you know whether a positive result records a preferred explanation or simply the inherent bias).

Halley begins the last paragraph by admitting a bias that he cannot correct:

> If it be objected that the water of the ocean, and perhaps some of these lakes, might at the first beginning of things, in some measure contain salt, so as to disturb the proportionality of the encrease [*sic*] of saltness in them, I will not dispute it . . .

How lovely, I said to myself. He is about to state the principle that bias must lie against an exception. I must note this and point it out to students. I read on and was not disappointed. Halley makes the argument with fine precision (continuing from the quotation above):

> . . . but shall observe that such a supposition would by so much contract the age of the world within the date to be derived from the foregoing argument. . . .

I smiled benignly, began to read on, and then experienced the moment of truth so like that classic scene of cartoon or comedy when the policeman sees a flying mouse or a walking snowman or a parade of jailbirds, smiles happily with a "how-nice, a-flying-mouse" look, then does a double take, drops whistle from mouth in astonishment and says, "A flying mouse!" Wait a minute! Halley is supposed to be arguing for an age *longer* than tradition, an expansion of biblical limitations. But he actually says that a bias he can't remove will make the earth seem *older* than it really is, the very kind of bias—one favoring your hypothesis—that *must* be avoided. (If a bag contains one hundred beans and you observe that one new bean is added each day, you will assume, by analogy with Halley's argument about originally saltless oceans, that beans have been added for one hundred days. But if the bag started with twenty-five beans, the process will only be seventy-five days old, not one hundred as you estimated. In the same manner, if the oceans started with some salt, but you assume they began saltless, your age by Halley's method will be greater than the true age.)

Oh dear (or something rather stronger), I thought. Does Halley have his methodology backward? What is going on? How can he be trying to expand the earth's age and admit a bias that will make it appear older? Either Halley was a methodological dunce or something must be desperately wrong with the traditional view that he was setting a minimal age for the earth. In fact, Halley is telling us that he has set a *maximal* age, and he is clearly damned pleased with himself. I read further (again continuing the last quotation):

> . . . the foregoing argument, which is chiefly presented to refute the ancient notion, some have of late entertained, of the eternity of all things.

So Halley thought he was doing the exact opposite of what all posterity has said he did. He argued that he was establishing a maximal age to refute a notion of eternity. We say that he was seeking a minimal age to expand the literal biblical chronology. Why—given the admirable clarity of Halley's words—have we so grievously misstated his intent.

Eternity is no longer an issue for us (in discussing the earth's duration). We all assume that our planet had a determinable beginning. Since we have not entertained this alternative for several centuries, we lack a context for grasping Halley's last paragraph. We read right through his words because they make no sense to us. We, as veterans of several creationist waves from Scopes to Arkansas, fully understand the threat to science of biblical literalism. We are therefore led to read Halley falsely in our light and see him as a fighter for expanded time rather than, as he insists, a measurer who would fix an actual date in order to eliminate the possibility of infinite existence.

Fortunately, I have spent much of the last two months reading the protogeologies of late seventeenth-century British savants (primarily Thomas Burnet's *Sacred Theory of the Earth*), while preparing a book on concepts of time in geol-

ogy. I was therefore predisposed to read Halley as he intended.

We can grasp why eternity seemed an even greater danger than biblical literalism only when we understand Halley and his generation as struggling to find the basis for a science of historical events (both Burnet and Halley were friends of Newton and members of a scientific generation with common goals). Burnet, for example, rails on and on through 400 pages against the idea of eternity; and he fights this great battle, or so he says, because eternity precludes the possibility of meaningful history defined as a sequence of distinct and recognizable events linked by ordinary ties of cause and effect. Burnet identifies, as his main enemy:

> . . . this Aristotelian doctrine, that makes the present form of the earth to have been from eternity, for the truth is, this whole book is one continued argument against that opinion.

If the earth is eternal, then no event can be distinctive. All must occur again and again, and we fall into incomprehension; for our struggles and dreams lose any meaning as unique events in finite time. Eternity destroys history; it "takes away the subject of our discourse," as Burnet writes.

Jorge Luis Borges, in his uniquely exquisite way, expressed the incomprehensibility of infinity in *The Book of Sand*. In this story, Borge procures an infinite book. He cannot find its end, for no matter how furiously he turns the pages, as many remain between him and the back cover. The book contains small illustrations, spaced 2,000 pages apart. None is ever repeated, and Borges fills a notebook with their sequence, never coming any closer to a termination. Finally, he understands that this precious book is actually monstrous and obscene; and he loses it permanently on a shelf deep in the stacks of the Argentine National Library. He has understood the dilemma of eternity: "If space is infinite, we may be at any point in space. If time is infinite, we may be at any point in time."

Halley sought to disprove this most unthinkable of systems by resolving Borges's dilemma and setting a definite point—an actual age in years—for the earth's beginning. Halley, in short, was fighting for history. If we view him as a great historical scientist who advanced his proposal for dating the earth as a blow for rationality itself, then we can understand the last paragraph and its message for us.

Halley fights for history from both sides; his short article is both a specific proposal for measuring the earth's age and a beautifully crafted defense of historical

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science in general. He does argue against biblical literalism—to gain enough time so that ordinary causes may shape geological history. Without time in abundance, we will need miracles to cram such richness into just a few thousand years. The traditional reading of Halley stops here.

But Halley insists that his struggle for a comprehensible history proceeds primarily from the other end, by stealing time from eternity—for the bias of his method can only justify its use against a claim for *greater* ages than he might measure. I think that we must take Halley at his word, for he was too astute a methodologist to misplay the primary criterion of bias in his last paragraph. The greater danger must have been the position that his method could refute because its biases erred in that direction. Halley believed that he had set a maximal age for our planet. Surely, the earth could not be infinite, for biases in Halley's method made it younger than his own measured maximum.

When we understand what Halley really sought, we can also grasp the reason for his failure. He was trying to establish a rational science of history. To do this, he needed a criterion that would change constantly in a recognizable way through time—so that each moment would be distinctly different from every other, thus avoiding Borges's dilemma. He thought that the accumulation of salt in oceans and lakes, linearly increasing through time, would provide such a criterion. The primary struggle of historical science ever since Halley has centered upon the search for phenomena that change constantly and therefore mark the passage of time. Halley knew exactly what history needed, but he chose the wrong criterion for interesting reasons.

Halley may have burst the bonds of biblical literalism, but he had no inkling whatever of time's true immensity. (The 100-million-year age so often attributed to him is Joly's nineteenth-century date using Halley's method. Halley himself never dared to think in more than thousands.) The clearest evidence for Halley's limited perspective, a notion shared by all contemporaries who tried to date the earth, lies within his argument about salt, when he laments that ancient Romans and Greeks did not measure the salinity of oceans:

> It were to be wished that the ancient Greek and Latin authors had delivered down to us the degree of the saltness of the sea, as it was about 2,000 years ago; for then it cannot be doubted but that the difference between what is now found and what then was, would become very sensible.

If Halley had recognized how infinites-

imally tiny a fraction of earth history these 2,000 years actually represented, he would not have been so confident that the increment between then and now could set a metric for determining the beginning itself. Two thousand years was an appreciable part of the tens, or at most, hundreds of thousands that his wildest fancies could conceive.

An earth as young as Halley imagined might have provided criteria for history in such simple physical processes as the influx of salt from rivers. But, as I argued above, simple systems generally equilibrate or reach some completed state over truly great durations. Quartz is quartz whether made a billion years ago or yesterday. Components of atmospheres and oceans reach equilibrium; they do not change steadily over billions of years. Unless we can find something truly big (fuel of a star) or numerous (number of atoms subject to radioactive decay) relative to time available, physical objects make poor criteria of history.

The best signs of history are objects so complex and so bound in webs of unpredictable contingency that no state, once lost, can ever arise again in precisely the same way. Life, through evolution, possesses this unrepeatable complexity more decisively than any other phenomenon on our planet. Scientists did not develop a geological time scale—the rod of history—until they realized that fossils formed such a sequence of uniquely nonrepeating events.

When I began these columns more than ten years ago, I chose for my general title a phrase from the last paragraph of Darwin's *Origin of Species*—"this view of life." I selected this passage because I love the science of history. Darwin used this phrase to contrast the richness of life's history with the timeless cycling of simpler physical systems, in particular, planets in their orbits. Halley had the brilliance to know what a science of history required, but he could not grasp why simple systems did not provide good criteria because he dared not even imagine how old the earth might really be. Darwin sensed the scope of time and knew that only life's complexity could map its richness:

> There is grandeur in this view of life . . . .Whilst this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning endless forms most beautiful and most wonderful have been, and are being, evolved.

Stephen Jay Gould teaches biology, geology, and the history of science at Harvard University.

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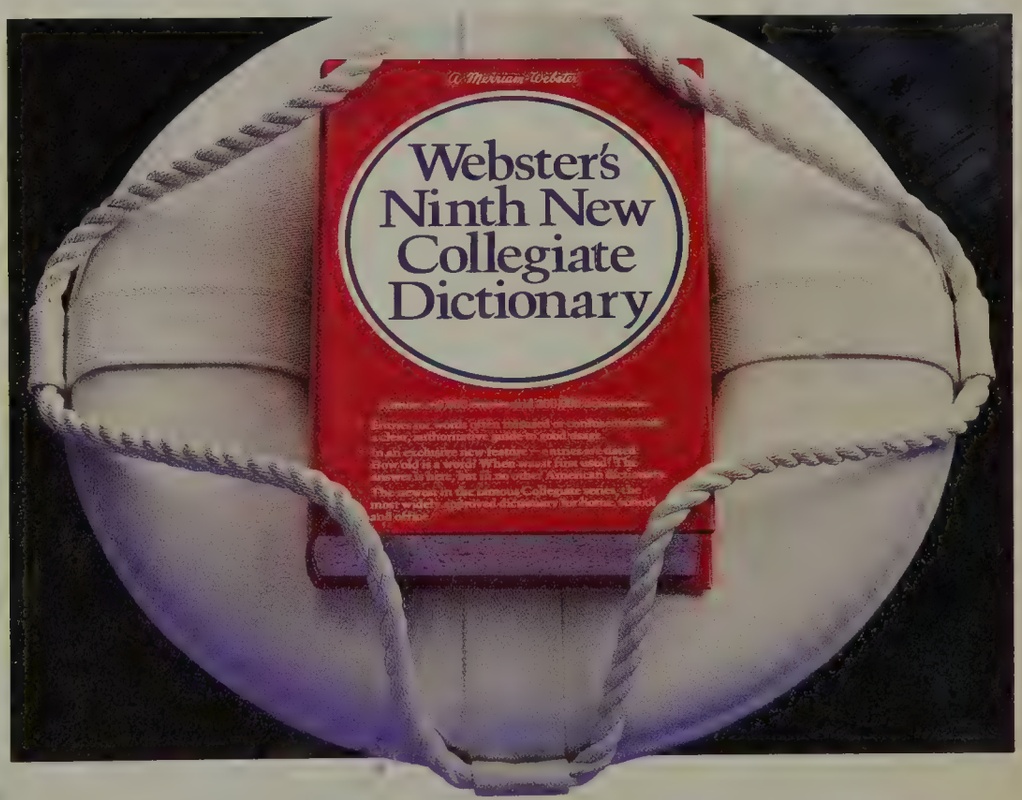

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Gift of the Mice People

Humans have often enjoyed the fruits of other animals' labors

by Stephen B. Vander Wall

Anyone who has tasted honey knows that people benefit from raiding the larders of other animals. Besides honeybees, many other creatures—rodents, shrews, moles, weasels and related carnivores, pikas, certain ants, some birds, and a few species of beetle—gather and concentrate food, though not all of the items they accumulate appeal to humans. Moles, for example, cache earthworms in their burrows; shrews hoard insects, snails, and small rodents in subterranean chambers; and weasels store rodents underground. Equally unappetizing to humans are the mice and insects secreted by sparrow hawks and the dung buried by dung beetles. Many birds hide food, but like the jays and nutcrackers that place seeds in the ground, most scatter their stores in widely spaced caches. These caches, palatable or not, are hard to find and each contains little energy. Other animal food stores, however, have been important sources of energy for humans and, in some cases, for their domesticated stock.

Primitive societies commonly exploited food set aside by animals. Before the turn of the century, Eskimos at Norton Sound, Alaska, collected roots and tubers from storage chambers excavated by the tundra vole. These chambers lie close to the soil surface, just below a layer of mosses and lichens, a short distance from the vole's grass-lined nest. In autumn, just before the first snowfall, women and children would jab the ground with pointed sticks, locating the caches by the ease with which the sticks penetrated the mossy cover. A single chamber could yield a peck or more of crisp, fresh roots. The cooked roots, a valuable adjunct to the Eskimos' standard winter diet of fish and meat, made a palatable dish similar to unripe sweet potatoes. The natives of Kamchatka, USSR, obtained roots from the same species of vole, whose Latin name, *Microtus oeconomus,* refers to its economically valuable habits.

Indians of the Missouri River Valley obtained beans and other wild vegetables from the storage bins of a small rodent that early natural historians referred to as the bean mouse. Lewis and Clark, in the report of their 1804–1806 expedition, were the first to describe the use of mouse food stores:

> When we stopped for dinner [Sacagawea] went out, and after penetrating with a sharp stick the holes of the mice, near some driftwood, brought to us a quantity of wild artichokes, which the mice collect and hoard in large numbers.

Years later, Lieut. G.K. Warren, the topographical engineer for the 1855 Sioux Expedition to the Dakota Country, reported:

> The groundnut, or [*Apios americana*], is very useful to the Indians. It grows very abundantly along the river bottoms, and is gathered in large quantities by a kind of wood mouse for his winter store. The squaws make a business, during the months of October and November, of robbing these little animals, and I have often seen several bushels of the tubers in a single lodge. They are boiled with dried buffalo meat, and make a rich and palatable dish.

The identity of the bean mouse was not established until October 1919, when Vernon Bailey, a senior biologist for the U.S. Biological Survey conducting fieldwork in North Dakota, made a special effort to capture the bean-caching rodent. He showed specimens of various mammals to knowledgeable Indians, and many identified the meadow vole as the rodent they had seen running from the larders. But others identified red-backed voles, white-footed mice, ground squirrels, chipmunks, harvest mice, and even weasels as the bean hoarders.

Still uncertain as to the true identity of the bean mouse, Bailey set out to find some caches and capture the rodent that prepared them. Proceeding to an area where the bean mouse was common, he readily found a small cache of beans and artichokes and captured two meadow voles in tunnels leading to the chamber. Much to Bailey's surprise, these voles belonged to a subspecies that he had only recently described in a manuscript. When Bailey published his description, he adopted the Latin name *Microtus pennsylvanicus wahema* for the new subspecies. This name was an adaptation of the one long used for these voles by the Omaha Indians, *intshunga wahema*, which means "burying mouse." Although other rodents also probably store wild

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The wood rat, the original pack rat, fills its den with foliage, twigs, and seeds.

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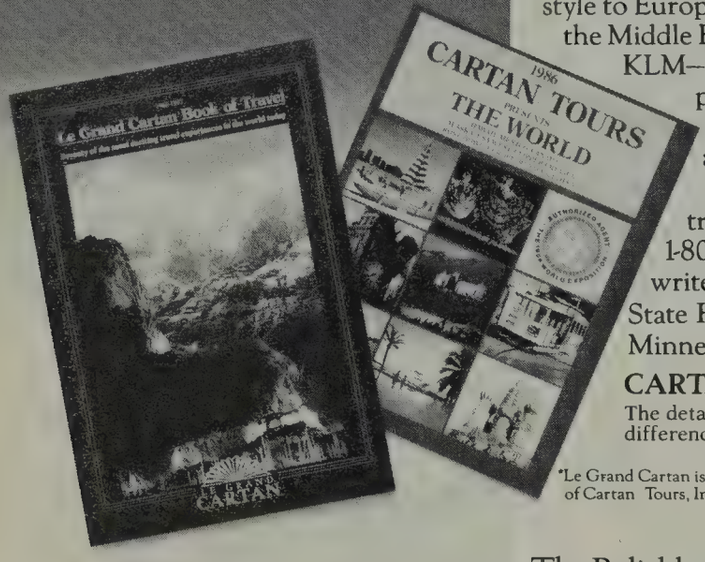

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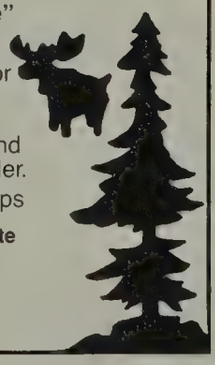

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Repletes, honey ants whose abdomens are distended with nectar and honeydew, cling to the roof of their underground nest.

beans and vegetables, this species seemed to be responsible for most caches used by the Indians of the Missouri River Valley.

The Indians, whose lore had it that the voles dragged beans home on leaves, described to Bailey the items typically found in the rodent storerooms. Ground beans—large beans that grow like peanuts on underground shoots—constituted most of the stores, but tubers of wild artichokes and tipsin and the roots of wild morning glory often turned up. Sioux Indians also obtained the star-shaped root of wild lily of the valley, which they considered not only good to eat but also "strong medicine." Indians sought these treasures in late October and early November, just as the rodents were completing the caches. Bailey learned that the Indians looked for places where several rodent trails converged in the dry grass or fresh snow, leading to tunnel entrances. To find the storage chamber, the Indians noted where the soft earth gave way under the pressure of a heel or they probed the ground around the burrow entrances with sharp sticks. Up to a peck of beans, tubers, and roots could be obtained from a single cache, and one Indian, who made a business of collecting the vegetables, claimed to have harvested as much as two bushels per day in this way.

The Indians thought of the voles as their helpers, the mice people. Melvin R. Gilmore, an ethnobotanist who studied the Indians of the Missouri River region, stated that

> women of the Dakota Nation . . . did not take the ground beans from the stores of the little animals which gathered them without giving some food commodity in return. They said it was their custom to carry a bag of corn with them when they went to look for the stores of beans gathered by the animals, and when they took out any beans

M.W. Larson; Bruce Coleman, Inc.

they put in place of them an equal quantity of corn. . . . They said it would be wicked to steal from the animals, but they thought that a fair exchange was not robbery.

One legend told of the punishment delivered to a selfish woman who took all the beans but left no food in exchange.

In addition to raiding the stores of the bean mouse, the Sioux Indians of Minnesota broke into muskrat caches, which are usually placed in large galleries dug into a bank. There the Indians found bulbs they called *psinchinchah,* which were probably duck potato or arrowhead. Charles Alexander Eastman, a Dakota Indian who became a physician, author, and lecturer, writing of his Indian boyhood, commented:

When our people were gathering the wild rice, they always watched for another plant that grows in the muddy bottom of lakes and ponds. It is a white bulb about the size of an ordinary onion. This is stored away by the muskrats in their houses by the waterside, and there is often a bushel or more of the *psinchinchah* to be found within. It seems as if everybody was good to the wild Indians; at least we thought so then.

Wood rat dens have yielded both nutriment and information on recent changes in plant communities. Wood rats store foliage and twigs from a wide variety of plant species, as well as some seeds, especially those of piñon pine. The Navahos and other Indians of the American Southwest relied heavily on piñon seeds, which they gathered from the cones or picked from the ground beneath piñon trees. They also collected the seeds from wood rat larders, as much as forty-four pounds from a single den.

The vegetation stored by wood rats, though largely inedible to humans, has proved valuable in another way. Often placed in sheltered sites, the nests may persist for thousands of years, occupied intermittently by different generations of wood rats. The animals construct their nests of assorted vegetation that, along with discarded food, is compacted by

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A muskrat deep in duckweed: the species may store more than a bushel of edible bulbs in its waterside galleries.

trampling and cemented together by an accumulation of the rodents' feces and urine. As time passes, new nest material and stored food may be added, providing a sample over time of the plants growing within about 100 yards of the nest.

Philip V. Wells of the University of Kansas was the first to recognize the value of the ancient nests for unraveling the history of plant communities of the American Southwest. By dating fossilized plant material, he was able to determine what plants grew in the vicinity of a nest at different times in the past. Comparisons of nests over large geographic areas have revealed that plant communities in the western United States and northern Mexico have changed markedly over the past 40,000 years, in response to glacial retreats and advances. For example, the single-leaf piñon pine, which now occupies a large portion of the intermountain region of Utah and Nevada, colonized that area only recently, 8,000 to 12,000 years ago.

Honey-storing insects provide resources that humans have enjoyed for hundreds of generations, both as food and as the basis for intoxicating beverages. Perhaps the most unusual example is the honey ant. Honey ants, found in arid and semiarid regions of North America, Asia Minor, southern Africa, and Australia, collect nectar and honeydew, a sweet exudate of certain plants and of juice-sucking plant insects. Using their distensible crops, the honey ants transport these fluids to subterranean nests. In the nests, certain members of the colony, known as repletes, imbibe so much of the sweet liquid that their abdomens become greatly enlarged and nearly spherical. These living receptacles avoid abrasion that would cause rupture by clinging to the ceilings of underground

chambers. Nests may contain more than 1,000 repletes.

Indians of the American Southwest considered honey ant nectar a delicacy. They pressed it from the repletes and used it as a condiment with meals. Sometimes the sweet liquid was squeezed directly into the mouth and the insect's body discarded; honored guests were offered a plate of grapelike honey ant abdomens with head and thorax carefully removed. The Indians believed that the nectar had medicinal properties when applied to bruises and swollen limbs, and they also prepared an alcoholic beverage from it.

The Aborigines of central Australia also sought the nectar of honey ants, and in places the landscape is pockmarked with excavations where nests were plundered. Keith C. McKeown, in *Insect Wonders of Australia,* gives a vivid description of how the honey was consumed:

> In eating them the native seizes each with the fingers by the forepart of the body and, after blowing off the dust, places the distended abdomen of the insect in the mouth, and bites it off, letting the slightly acid honey flow over the tongue with evident satisfaction. The abdomen is swallowed, while the remainder of the body is discarded.

People have also appropriated animal food caches for the benefit of livestock. In Manchuria, the cattle and sheep of Mongolian herders ate hay cured by the Dahurian pika, a small, rabbitlike animal. This species of pika prepares hay in the fall from grasses and forbs just as pikas do in western North America. In Manchuria, however, pikas live in large colonies and excavate burrows in the soil of the high steppes and semideserts, behavior reminiscent of prairie dogs. They construct hay piles on the ground near their burrows, and in large colonies, thousands of the two- to five-pound haystacks dot the landscape. In winter, the herders drove their

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stock to pika colonies and let their hungry animals feed on the hay.

Cones stored by red squirrels have been a source of conifer seed for reforestation. Red squirrels collect large numbers of intact, mature cones and bury them in middens, the accumulations of forest litter under habitual feeding sites. In the coniferous forests of western North America, two to five, even fifteen bushels of cones can be obtained from a single cache. The species include Engelmann spruce, blue spruce, Douglas fir, western white pine, lodgepole pine, and ponderosa pine. Beginning in the early 1900s, U.S. Forest Service workers dug up the cones, as did individual collectors who sold the cones to the Forest Service or to nurseries. The cones were shipped to centralized processing plants where the seeds were extracted and cleaned.

Taking the cones from the squirrels eliminated the need to climb or fell trees. And, since squirrels harvest only disease-free cones containing ripe seeds, the yield was reliably high in quality. Because cones in middens remained closed and the seeds viable for extended periods, squirrel caches were also good cone sources long after those in treetops had opened and shed their seeds. These advantages made this method of collecting conifer seeds cost effective. In the late 1930s, for example, Douglas fir cones could be collected from caches for about fifty cents per bushel, less than half the cost of other methods. In the late 1960s, Robert B. Finley, Jr., a mammalogist for the U.S. Fish and Wildlife Service in Denver, concluded that

> the great bulk of conifer seed used in the Pacific Northwest and the Northern and Southern Rocky Mountain regions is initially harvested by [the red squirrel]. There seems to be no other source at present from which the required amounts can be obtained at reasonable cost.

The use of seeds from red squirrel caches seems to be declining. Today there is an emphasis on tree genetics for breeding fast growing, disease-resistant trees with improved form. Foresters therefore prefer to select seeds of known parentage, which are not available from squirrel middens. Tree-seed farms are replacing the red squirrel as the primary source of conifer seeds for some species.

Human exploitation of other foods collected by animals has also gradually diminished during the present century. By the time of Vernon Bailey's 1919 discovery, only a few Indians still sought the stores of the bean mouse. The crisp and delicious vegetables once formed an important part of the winter diet of the hunting tribes of the Missouri River Valley, but by the 1920s, gardens of grain and vegetables had eliminated the need to empty the underground caches. Even the collection of wild honey is less common these days, although the tending of bee hives has become a major food industry. Primitive cultures once held food-hoarding animals in high esteem, often ascribing mythical importance to them. Today, few people take advantage of the industrious habits of most of these animals.

Stephen B. Vander Wall is an adjunct research assistant professor in the Department of Biology, Utah State University, Logan. He has researched the food storage behavior of animals for the past fifteen years.

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The red squirrel's pine cone collection is coveted by the Forest Service.

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Chuck Place

Olympic Rain Forest, Washington

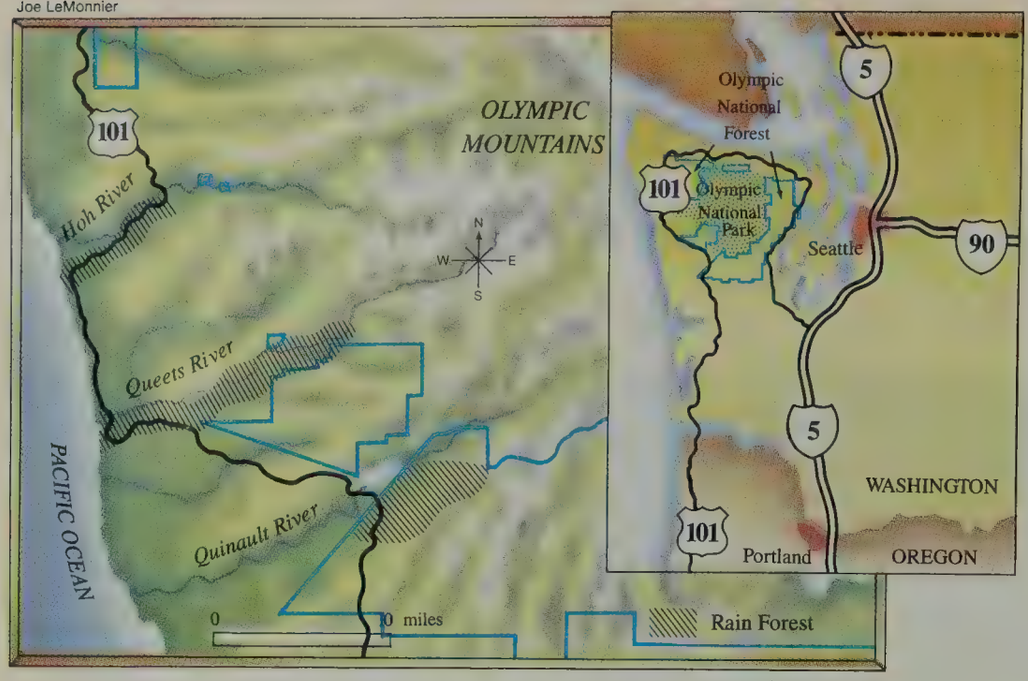
by Robert H. Mohlenbrock

Several years ago I was surprised to learn that an area in the Olympic Peninsula of northwestern Washington State was referred to as a rain forest, a label that for me conjured up a picture of a steaming jungle. Since the peninsula is at least two thousand miles north of the tropics, I knew this image was inappropriate, but I could not imagine what a temperate rain forest would be like or how it had developed in that particular place. To satisfy my curiosity, I planned a trip there.

My first introduction to the Olympic rain forest came as I hiked along a nature trail a short distance from the Quinault Ranger Station in Olympic National Forest. Quinault is one of three valleys harboring prime temperate rain forest. A foglike mist hung heavily in the air, enshrouding tall trees draped with countless epiphytes, or air plants. I began to tick off the similarities between what I was seeing and the typical rain forest of the tropics: many trees soared to heights of more than 200 feet; the tallest trees in the canopy were evergreens; there was a middle layer primarily of deciduous trees; abundant epiphytes clothed the trees; and the air was moist. (A check with the nearest weather station revealed that rainfall in the valleys is 120 to 180 inches each year, the highest amount anywhere in the conterminous United States.)

Despite many similarities, however, there were differences between this temperate rain forest and a tropical one. The tall canopy of a tropical rain forest is created by many species of broad-leaved, usually slender-trunked evergreens, while Olympic is dominated by only four species, all needle-bearing conifers with exceptionally thick trunks. An abundance of woody vines, or lianas, hang from the tropical giants, while vines are practically absent in Olympic. The epiphytes on the branches of the tropical trees are mostly flowering plants, primarily orchids and bromeliads, whereas mosses, lichens, liverworts, and ferns grow on the trunks and branches of the temperate trees. The lower layer of woody plants in a tropical rain forest consists of tree ferns and bamboos; in Olympic, the shrub layer is sparse and consists mainly of vine maple, huckle-

Joe LeMonnier



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berry, and devil's club. And while the tropics are hot, Olympic is cool and mild.

Quinault Valley and the more northerly Queets and Hoh valleys lie on the southwestern flank of the Olympic Mountains, a part of the Coast Range, which parallels the Pacific Ocean shore from British Columbia to California. The broad, U-shaped valleys were carved out thousands of years ago by glaciers that edged slowly down the mountains. Today, the Quinault, Queets, and Hoh rivers, which flow through these valleys, are fed by remnants of the Ice Age, the glaciers that persist on the highest ridges.

Mount Olympus (7,965 feet), which caps the range, is only thirty-two miles from the Pacific Ocean. As moisture-laden clouds blow inland from the ocean, they meet the mountain barrier and are swept upward, where the chill air causes them to condense and release their water. The resultant ten to fifteen feet of rainfall each year is reflected in the phenomenal sizes of the four conifers that dominate the Olympic rain forest—Sitka spruce, western hemlock, Douglas fir, and western red cedar. The Sitka spruces account for about one-third of the trees. They are much larger here than anywhere else in their range, sometimes reaching heights of 250 feet, with trunk diameters of 13 feet. Western hemlocks are the next most abundant; they stretch more than 200 feet and their trunks may exceed 8 feet in diameter. Douglas firs grow nearly 300 feet tall; one mammoth has a diameter of 15 feet. Western red cedars may be only half as tall, but they often have greater girths. One measures nearly 22 feet in diameter.

Over time, some of these large trees crash to the forest floor and set off a chain of events destined to last several hundred years. The fallen trees are quickly invaded by borers searching for food and a place to lay their eggs. The holes made by these insects provide a niche for fungal spores to lodge. Soon hundreds of fungi penetrate the fallen log, causing decay. Before long mosses and lichens find a home on the downed tree, and the seeds of herbs, shrubs, and trees sprout there. The tree seedlings seem to benefit from the presence on their roots of fungi that convert nutrients to usable forms.

Because they help promote the growth of a new generation of trees, the fallen conifers are known as nurse logs. The tree seedlings on a nurse log develop slowly at first, since their roots are not long enough to encircle the fallen trunk and reach the soil, but once the roots touch ground, the seedlings grow rapidly.

Owing to competition, only a small number of the hundreds of seedlings that sprout on a nurse log reach maturity. After scores of years, with the old nurse log nearing total decay, perhaps as many as fifteen trees will survive, arranged as a colonnade. When a nurse log has totally decomposed, each living tree in the colonnade seems to be standing on stilts, where its roots grew around the old log on their way to the soil. Not until many years later are the openings beneath the stilts filled in. Although thousands of tree seedlings also germinate on the forest floor, most of them are unable to compete with the dense growth of mosses and herbs that carpet the ground, so most of the forest's tree regeneration depends on nurse logs.

Tall trees also topple to the ground in tropical rain forests, and the gaps they leave in the canopy admit sunlight essential to the growth of certain seedlings. Often these seedlings develop from seeds that lodge in the bark of fallen trees. Although some tropical trees decay rapidly in the intense heat and humidity, many of them have extremely hard wood that impedes decay. These then become tropical nurse logs, much like the fallen trees in the temperate Olympic rain forest.

"This Land" highlights the biological phenomena of the 153 U.S. national forests. Robert H. Mohlenbrock is distinguished professor of botany at Southern Illinois University at Carbondale.

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Trees grow along remnants of a nurse log in the Olympic Peninsula's Hoh Valley.

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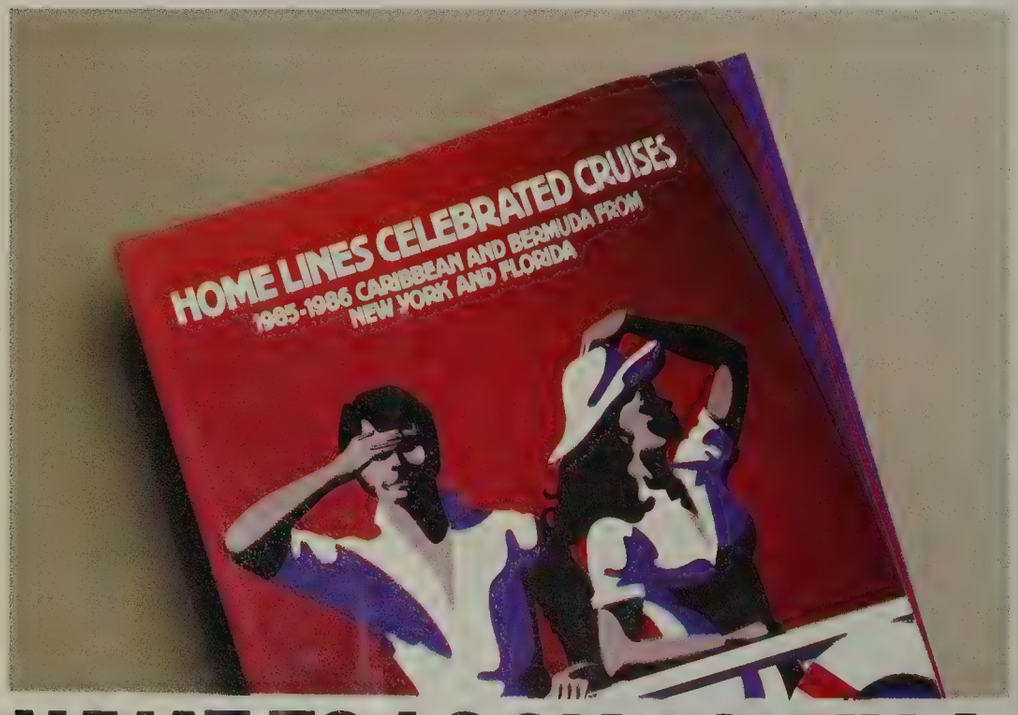

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Fitness Fallacies

Who will have the most grandchildren—the skinny, unathletic Harvard M.B.A. or the high-school football coach?

by Joseph D. Wassersug and Richard J. Wassersug

The current pervasive push toward the body perfect is based on some semantic misunderstandings that sorely need clarification. Much of the problem, we think, lies with popular understanding of the term fitness. Many of the ardent joggers we know seem to think that with the achievement of "fitness," they will not only be healthier but also live longer. For others, if we are to judge by the most-advertised exercise programs, fitness is simply the attainment of the body beautiful, a state that has a lot more to do with physique than physiology.

While there is no denying that vigorous exercise may improve one's sense of well-being (comparable, say, to Zen meditation or vegetarianism), there is no evidence that running five miles a day, for instance, improves life expectancy or even appreciably enhances health. A long-term epidemiologic study of nearly 17,000 Harvard University graduates (published in 1984 in the *Journal of the American Medical Association*) found that the risk of coronary heart disease was lower in people who claimed to exercise enough to burn off the equivalent of 2,000 kilocalories (kcal.) a week than in those who claimed that they exercised less. But while this may sound like a lot of energy, it doesn't amount to a lot of exercise. A normal 165-pound man, for example, can easily use up that many calories through three to five hours a week of routine walking on level ground.

Carefully prescribed exercises may increase the chances of survival in some people—primarily those who have had heart attacks or coronary surgery. Because walking pumps blood back to the heart, it reduces ankle edema and often improves breathing in patients with congestive heart failure; regulated exercise

may also help those who suffer attacks of angina pectoris. But the physical fitness that daily rigorous exercise is supposed to produce does little to prevent heart disease in otherwise healthy people. And there is no evidence at all that physical fitness protects against the other maladies that are common causes of human mortality. Cancer of the breast, lungs, or bowel; Alzheimer's and Parkinson's disease; and a great variety of anemias and dystrophies kill the fit and the unfit with equal ruthlessness.

If one is in generally good health (at the right weight for one's height and age, not smoking, not eating a lot of foods rich in saturated fats), then excessive physical exertion, that is, much beyond what is needed to maintain ideal weight, does nothing to improve life expectancy. Regrettably, few physical-fitness fanatics seem willing to accept this. Heavy-duty iron pumpers and triathalon trekkies will argue forcefully that they are *sure* that there *must* be many medical studies to show that heavy exercise (for example, burning off more than 2,000 kcal. a day above basal consumption levels) increases life expectancy. But if such a single, controlled study exists, it would be known, cited, and re-cited in the medical literature. There is no such study.

On the other hand, there is some evidence that the opposite is true. Since vigorous exercise initially increases heart rate and output, raises blood pressure, and, to some extent, deprives the heart of oxygen, it may contribute to early death and dis-

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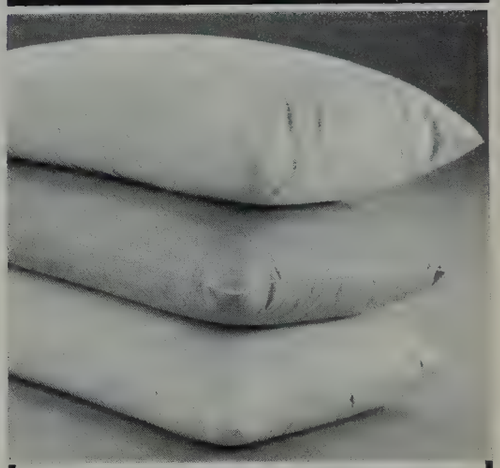

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ability. Exercise guru James Fixx died at 52 and Olympic oarsman John B. Kelly, Jr., clad in his running clothes, died at 58. While many runners who die suddenly had preexisting heart disease (and may have been aware of it), other deaths while running happen to those with no known earlier heart impairment and no significant myocardial or coronary artery disease detectable at autopsy. These deaths have been attributed to occult biochemical or electrophysiological derangements.

Writing recently in *Cardiovascular Reviews and Reports,* Drs. A. Sadaniantz and P.D. Thompson have suggested that coronary spasm may also play a role. Reviewing the literature, these authors found that the hourly death rate while jogging was about seven times that of those engaged in more sedentary activities. The death rate was particularly high in men unaccustomed to physical activity. They conclude: "Exercise and fitness may help prevent, but do not guarantee protection against, an exercise death. Other risk factors such as hyperlipidemia [too much fat in the blood], cigarette smoking, and hypertension are more powerful predictors of CAD [coronary artery disease] than sedentary behavior."

We don't at present have all the answers to longevity—there may be as-yet unexplored factors of climate, nutrition, and heredity. Geographically, greatest longevity is achieved by the mountain dwellers of Turkestan and the farmers of Vermont. Among professions, orchestra conductors and concert musicians—not athletes or heavy laborers—live the longest.

The myth of workout longevity may stem from confusion about the definitions of fitness. Biologists use the term in several different ways. In the field of physiology—the field that pertains to joggers—the definition of fitness is "increased capacity for work." What this means is that a person who regularly runs five miles each day will be more capable of running five miles the next day *if* he is alive the next day. The fit person can do more work in a single day than the person who is not fit. This, of course, is a good enough reason to get some exercise now and then. It does not follow, however, that the fit person who jogs five miles a day will have more days in his life in which to jog than a person who runs, say, only a half mile three times a week. The older person can do as much as a younger person but needs more time to do it. Age slows down even the fittest.

The latest scientific work on the relationship between exercise and heart attack suggests that brief bouts (three to five minutes a day) of extremely brisk exercise are all one needs to give one the same statistical probability of living to an old age as sweating up a storm for thirty or fifty minutes a day.

At the other extreme, there is considerable data to show that overexertion can kill at a young age. While regularly increasing the heart rate for *short* periods by exercise may enhance coronary circulation, prolonged episodes of tachycardia (a racing heart) are definitely damaging. We don't know exactly where the curve for the risk of coronary heart disease versus calories consumed in exercise per week turns upward, but researchers studying the relationship between health and exercise acknowledge that at some point the curve must turn upward. For all individuals there is a point where they are burning off too many calories and increasing the risk of injury and death. If you need a long time to recover from your workout, you might do well to discuss your exercise program with your doctor.

The myth that exercise and longevity are linked is based on two misconceptions. The first is the old idea that helps keep over-the-counter vitamin sales so high,

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namely, "if a little is good for you, then a lot is much better." Yet high doses of the fat-soluble vitamins, such as A and D, are definitely toxic; the B and C vitamins are readily excreted by the kidneys and thus an excess provides no more health benefits than the minimum daily requirement. The more-is-not-better principle also applies to physical exercise. We may live longer if we have a certain, minimal amount of exercise. We will not necessarily live longer if we have ten times that amount.

Perhaps a second source of the myth about exercise and longevity stems from a misunderstanding of the phrase "survival of the fittest," which is associated with Darwin's *Origin of Species*. Actually, it wasn't Charles Darwin who coined the phrase, but the social philosopher Herbert Spencer. Darwin liked the one-liner enough at the time to adapt it for use in his book. But Darwin's own definition of fitness did not directly concern individual survival. There are thus really two definitions of fitness in the Darwinian literature—Darwin's and Spencer's; but both are quite independent of the physiologists' definition. To Darwin, and to all evolutionary biologists working today, increased fitness means increased fecundity. In plain English, fitter organisms leave more offspring than less fit organisms. According to Darwin's definition, a man who died young, but left more children (and potential grandchildren) than other people, would be more "fit."

Both the physiological and the Darwinian definitions of fitness may concurrently apply to many organisms. During the rutting season, a male moose that can last the longest in a duel with another moose will probably increase his access to a female moose at the height of her reproductive cycle (more sex, more offspring; *ergo*, increased Darwinian fitness). But only in a fairy-tale world—where kings give away daughters to knights who win athletic events against other knights—does the increased physiological fitness necessary to win the contest also mean increased Darwinian fitness for the victor.

Perhaps what attracts people today to physical fitness programs is an unconscious wish to improve their fitness in the Darwinian sense. If one jogs and pumps iron to attract members of the opposite sex, then increased physiological fitness could lead to increased Darwinian fitness. There are, however, two caveats here. First, attracting sexual partners does not in itself lead to increased Darwinian fitness. Attraction must lead to increased fecundity: there must be more offspring for there to be an increase in evolutionary fitness. The skinny, unathletic Harvard M.B.A. who earns $300,000 a year may be as likely to attract compliant females as the high-school football coach who earns $30,000. But neither is guaranteed a houseful of grandchildren. For modern man, neither fiscal nor physical fitness forecasts fecundity.

Second, rigorous programs of physical exertion can actually interfere with the organism's ability to reproduce. A study published last year in the *New England Journal of Medicine* documented that women athletes on a rigorous training regime ceased to menstruate and, presumably, to ovulate. Women who continually push themselves to their physical limits are on a course leading to the extinction of their family line. Surely, the sacrifice of evolutionary fitness for a hypothetical increase in physical fitness carries the more-is-better idea to its absurd conclusion.

Joseph Wassersug is an internist and the author of seven health books. His son, Richard Wassersug, an evolutionary biologist, is associate professor of anatomy at Dalhousie University Medical School in Halifax, Nova Scotia.

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A male yellow-rumped cacique sings and displays
Warren Martin Hern

Social Security for Birds

Yellow-rumped caciques crowd into noisy colonies where everyone wants to be an insider

by Scott K. Robinson

One September afternoon in 1980, I was paddling a canoe along the edge of a lake in Amazonian Peru when I heard a commotion coming from a tree overhead. Dozens of yellow-rumped caciques, orioolelike members of the blackbird family, were calling loudly and flying back and forth over a troop of brown capuchin monkeys that leaped from branch to branch toward the cacique colony. Within minutes the capuchins had surrounded the colony and ransacked all twenty-four nests on its periphery. The capuchins simply reached into the entrance hole of each hanging, pouchlike nest and extracted nestlings as if taking presents out of a Christmas stocking. One male held two nestlings in his left hand while pulling a third out of a different nest. When the capuchins approached the colony's central nests, however, they were repelled by a swarm of wasps that poured out of their huge nest in the cacique colony. After each unsuccessful attack on the nests in the center, the monkeys retreated to the branch below the colony, pulling wasps out of their fur. Eventually the capuchins gave up and the central nests remained unharmed.

The wasps provided the caciques with some protection from the capuchins, but only for the birds closest to the wasps' nest. Why, then, did many females nest at the more vulnerable edge of the colony? How did some birds manage to monopolize the safest sites? During the last six years, I have studied the various ways that caciques avoid nest predation and how these defenses relate to the birds' social behavior.

My base of operations, Cocha Cashu Biological Station in southeastern Peru's Manu National Park, is surrounded by humid tropical forest and situated on an oxbow lake, or *cocha*. (*Cochas* form when a meander loop of a river becomes isolated from the main river channel.) Each *cocha* of the Manu river contains a distinct population of caciques. Cocha Cashu usually has a population of fifty to one hundred adult females, half as many adult males, and a shifting population of juveniles. During my study, I caught and banded more than 700 caciques, putting distinctive colors on the legs of each bird so that I could recognize individuals. Manu National Park is remote and still has natural populations of many potential nest predators that have been exterminated in more accessible regions. Researcher John Terborgh and his collaborators have found thirteen primate species near the field station. White-fronted capuchins, brown capuchins, and squirrel monkeys, three species that attack cacique colonies, abound in nearly all habitats. Great black hawks, Cuvier's toucans, and black caracaras, all common, also attack cacique nests. None of these predators specializes in bird nests; most could be classified as "petty" nest predators. Capuchins, squirrel monkeys, and toucans usually eat fruit, nectar, and insects; caracaras scavenge and eat insects; while great black hawks eat frogs and snakes.

Cacique colonies, however, are inviting and conspicuous targets for predators. The cacique is a black, robin-sized bird with a pale yellow bill, light blue eyes, and brilliant yellow patches on its rump, tail, and wings. At colony sites males, 50 to 60 percent heavier than females, display and sing loud, harsh songs that mimic the sounds of more than one hundred species of birds and mammals. When many males sing simultaneously, as is often the case, they can be heard more than a quarter of a mile away. Caciques also nest in the open along the edges of lakes and in isolated forest trees. Within these colonies, bulky nests are often crowded into a central interwoven cluster. The cacique's contrasting plumage, loud voice, and habit of nesting in dense colonies in the open make its colonies an outstanding feature of tropical forests. At times caciques seem to be advertising the colony's location to potential nest predators.

Only after I had witnessed dozens of attacks did I begin to understand how caciques elude nest predators. The birds minimize the chances of being attacked by tree-climbing mammals, such as monkeys and opossums, by nesting in isolated trees and around wasp nests. Islands also provide protection from these mammals, which seldom cross open water, and from the many snakes that regularly prey upon bird nests. Snakes cross open water only at great risk. Undisturbed Amazonian lakes abound in black caimans, crocodilians that range from three to more than eight feet in length. Of the two snakes I have seen swimming near a cacique colony, one was captured and eaten by a caiman. The only snake I ever saw in an island colony reached the spot during a flood when there were no caimans present. A giant otter later caught and devoured this snake. Caimans, however, exact a toll for the protection they provide the birds. Most young caciques that fall into the water are eaten by caimans stationed under the colony trees. Cacique fledglings swim strongly, and most would survive in the absence of caimans.

Wasp nests protect against arboreal mammals and possibly against other birds and snakes. Caciques and many other birds build their nests near those of paper wasps, which attack any large animal that approaches their nests, and until the first few nests are built, harass the birds themselves. Research biologist Neal Smith has found that wasp nests also provide protection against botflies, which lay their eggs

cott Robinson

Left: A tree on a tiny island in an Amazonian oxbow lake is arrayed with some 150 pendent cacique nests. Below: A white, bell-shaped paper-wasp nest shares the branches with woven cacique nests. Female caciques vie for nesting sites on islands and near wasp nests because these locations offer protection against some predators.

oug Wechsler

on cacique nestlings. Botfly larvae burrow into the nestlings and develop under their skin. Nestlings afflicted by more than seven botflies usually die. The mechanism by which wasps protect caciques from botflies is unknown.

Suitable cacique islands and wasp nests, however, are in short supply in the Manu area. Only two of the eleven major oxbow lakes of the Manu River have islands. There is just one tiny island on Cocha Cashu, supporting a single, thirty-foot-high tree and separated from the marsh by just forty-five to sixty feet of open water. By mid-February, the end of the seven-month nesting season, the island tree on Cocha Cashu is usually festooned with thirty to one hundred active nests; entire branches sometimes break off and fall into the lake. When wasp nests appear on forest trees, as many as thirty-five females may crowd their nests into the branches nearest the insects.

Colonies protected by neither water nor wasps will usually be plundered by snakes or monkeys. Twelve of fourteen colonies in marsh shrubs near my study area were destroyed at night, probably by snakes; and eight of eleven colonies in lakeside trees were destroyed, mostly by monkeys. Females are three to ten times more likely to nest successfully on islands and around wasp nests than in marsh shrubs or lakeside trees.

Nesting on islands provides no protection against birds of prey, which can reach any colony and might even be attracted to a concentration of nests. Unlike mammals, birds must tear holes in the thick, intricately woven nests to search inside for eggs and nestlings. This difficult and time-consuming process opens two possible lines of defense for caciques. When toucans and caracaras are busy tearing at nests, they are vulnerable to attacks from caciques, which dive down and peck them on the rump. If mobbed by enough caciques, toucans and caracaras usually give up and leave the colony. By nesting in interwoven, synchronous clusters within colonies, caciques are assured of having enough neighbors to help them drive out most birds of prey. Isolated nests suffer four times the avian predation rate of clustered nests.

Caciques refrain from attacking great black hawks, perhaps because the raptors pose a danger to adult birds or are too large to be daunted by mobbing. When great black hawks strike colonies, most caciques simply leave the tree. These long-legged hawks shake each nest before ripping it apart, a behavior that may provide information on the contents of each nest. If the first three or four nests a hawk shakes are empty, it usually gives up and flies off. This happened nine of the eleven times I witnessed a great black hawk raid on a cacique colony. The most successful attack occurred at a colony in which nearly all nests contained young. Having found nestlings in the first three nests, the hawk shook and tore each one open. During the next four days, it returned seven times and preyed upon twelve more nests; the only untouched nests were so well hidden among abandoned ones that the hawk never found them. The best defense against black hawks, then, is a nest hidden amid a "ghost town" of abandoned ones.

How do caciques go about securing the best nest sites? Females compete for nest sites and build nests with no help from males. Nesting is nearly continual during the mid-July to mid-February breeding season. At any one time, however, there are local pockets of synchronous nesting within colonies. The most intense fights occur when one female tries to take over another's nest site in one of these synchronous clusters. Takeover attempts occur most frequently during the first few days of building in clusters on islands and around wasp nests, the sites that suffer the least predation. During these encounters, females grapple in midair and plummet downward until they crash into foliage or the water below the colony. During one such fight, a female broke her wing and fell into the water where she was immediately eaten by a caiman. Heavier females usually win fights, perhaps because they are generally stronger. As a result, heavy females control the safest nest sites and force smaller females to nest in more vulnerable colonies or exposed positions within colonies. In the capuchin attack I described, most of the females nesting on the edge of the wasp nest colony were smaller than those nesting in the center. Therefore, a female's weight is a major factor correlated with nest safety and subsequent reproductive success.

Access to nest sites is not entirely decided by combat. A female that has nested several times in an area begins to associate with other long-term residents, for whom she shows great tolerance.

Scott Robinson

Below: A black caiman floats in an oxbow lake. Caimans attack snakes that pose a threat to caciques, but they also eat any birds that may plummet from overhanging nests. Right: A brown capuchin monkey raids a cacique colony. Birds are not a major food source for capuchins, but groups of the monkeys often storm cacique colonies, reaching into nests and grabbing eggs and young birds.

Doug Wechsler

These veterans seldom try to usurp each other's nest sites, rarely steal nest material from each other, and allow other long-term residents to attach their nests to their own. These densely interwoven nest clusters provide the best protection against birds of prey. As experienced nesters, residents are also able to form new colonies quickly, an important advantage when a new wasp nest is constructed. Wasp nests are nearly always colonized first by long-term residents, which monopolize the choicest nest sites—those that are closest to the wasps.

Coalitions of mutually tolerant female caciques are not likely to consist of kin, as they do among most mammals and birds with comparable social behavior. Cacique females leave populations in which they are born, and each female seldom raises more than one nestling from any given brood. Few opportunities exist for the establishment of sibling groups or matrilines. Since each individual benefits from nesting close to others, such coalitions are mutualistic and can evolve even if the individuals are unrelated.

Newcomers—females that are nesting for the first time in a population or that have lost a previous nest to predators—must fight to establish their first nest site. Long-term residents attack any newcomers that try to settle in a cluster they dominate. Newcomers that manage to establish nest sites often have to defend them against takeover attempts by later-arriving females. Residents also prevent newcomers from founding nest sites by confiscating nest material, such as vines and strips of palm leaves. Sometimes resident females simply fly up to a newcomer and forcibly take the material. Such a move can result in a tug of war in which as many as five females pull at the same bit of nest material. But more often, residents simply filch material from the nest as soon as the newcomer leaves the colony in search of more. Some new females never complete their nests. Only hefty newcomers can withstand attacks by residents and establish safe nest sites. One heavy newcomer turned the tables by robbing the long-term residents herself. By remaining at the colony, this newcomer prevented the smaller residents from robbing her nest and built her own nest almost exclusively from stolen material. Another heavy newcomer withstood takeover attempts by five different long-term residents during a two-week period.

Large size is therefore especially important for young females that have not yet established residence in a population. Females wander widely when young and become residents in an area only when they establish a nest site that escapes predation. By their fifth year (the third year of adulthood), almost all females have become residents in a population and no longer need to fight as often to secure good nest sites. For this reason, they are relatively unaffected by the weight loss that occurs after their first two or three years of adulthood. Females five years and older are on the average 10 percent lighter than three- and four-year-olds, a substantial reduction in weight for a bird. Many old females are so small that they probably could never establish nests outside of clusters of other old-timers. Weight loss reflects the accumulated stresses of many nesting attempts or may indicate that older females no longer need to gain weight to establish and defend high-quality nest sites. Old, small females are about

as successful in gaining access to safe nest sites as heavy, young females. Each female fights when young and cooperates when old. Jaroslav Picman of the University of British Columbia has found that female red-winged blackbirds may form coalitions and cluster their nests to defend against marsh wrens, which puncture eggs. Nest predation may play a far larger role in avian social organization than has previously been recognized.

The clustering of females in dense colonies provides an opportunity for males to monopolize mating opportunities. Male caciques gather at colony sites to compete for females but do not help build nests or incubate and feed young. Slight, dull-plumaged first-year males seldom visit colony sites. Second year (adolescent) males, much like females in plumage, visit colonies regularly but badger females and their young, chasing females back and forth across the lake, attacking females inside nests, and harassing fledglings as they leave the colony. On rare occasions, adolescent males enter nests and kill nestlings, a behavior of no apparent adaptive value. Many of the young that fall victim to caimans are knocked into the water by adolescent males. By their third year, males reach adult plumage and size and stop harassing females. Adult males sing and display in colony sites and begin to associate with females both at and away from the colony.

Mating takes place in the forest, possibly because mating attempts in the colony are always disrupted by other males. For this reason, males can be assured of paternity only if they consort with and guard each female throughout her egg-laying period. Males begin consorting with females when the nest nears completion and stop the day before the second egg is laid—a period of three to five days. When consorting, males remain within three to six feet of the female at all times and drive away all other males. Usually, there is only one full-time consort male per female, though other males occasionally associate with the consort pair for short periods. Copulation occurs when the female solicits the male. When a male stops consorting with a female, he usually switches immediately to a new female. In those colonies characterized by nearly continual nest building, some males consort with as many as twenty-five females consecutively.

Although females outnumber males two to one in the population at large, intense competition among males for females is the rule, because males associate with females only during the egg-laying

period, while nesting is spread out over seven months. On any given day there are usually three to twelve males for every egg-laying female in a colony. Which of these males become consorts is determined by dominance. When a new male arrives at a colony, he engages in a series of spats with entrenched males. These squabbles sometimes escalate to aerial battles and prolonged matches during which contestants face each other and call loudly. I once saw two grappling birds fall right into the jaws of a caiman presumably on the alert for just such an occurrence. One male escaped, the other was eaten. Each fight results in a clear winner and loser. The winning male can supplant the loser from anywhere in a colony and take over the loser's consort. By tabulating the wins and losses for all sixty adult males in my study population, I was able to construct a dominance scale that was roughly linear: If male A is dominant to B, and B is dominant to C, then usually, but not always, A is also dominant to C. Dominance is largely correlated with weight. Two factors are involved. Heavy males tend to win fights, and smaller males rarely challenge larger ones. Males that differ widely in size seldom actually fight; most disputes are settled after a brief encounter in which both males face each other while hovering in the air. The smaller bird usually concedes dominance by flying away first. Males of similar size, however, usually have to grapple to confirm dominance.

High-ranking males, those at the top of the hierarchy, gain preferred access to females both at and away from the colony. Such dominant males sing and display from the center of nest clusters and do most of the consorting. Males from the top quarter of the hierarchy consort with and defend an average of ten females per breeding season, while males from the bottom half average less than one consortship per season. Dominance also determines which males consort with females in diverse groups of mammals—baboons, rhesus monkeys, elephants, bison, cape buffalo, and giraffes. The discovery of this mating system in caciques is the first documentation of the relationship between dominance and mating success in polygynous birds. There is growing evidence that the monogamous but closely related brown-headed cowbird may also form consortships based on male dominance.

Low-ranking males can either leave the colony and try to mate elsewhere or they can resort to "satellite" behavior. Satellite males perch on the edge of colonies; blend-

Doug Wechsler

Two female caciques wage a tug of war over a scrap of nest material. The stakes in such disputes are high. Consistent winners are more likely to nest in safe sites and avoid attack by birds of prey such as the great black hawk, below. The hawk shakes each nest to determine its contents before tearing it apart. If the first few nests are empty, the hawk gives up, leaving any hidden nests untouched.

Warren Martin Hern

ing patience and opportunism, they succeed in mating. They consort with females that are still building nests, follow any females left temporarily unattended by dominant males, and double up with dominant males that are consorting with females. I have also seen satellite males disrupt mating attempts by dominant consort males. Because of the ubiquity of satellite males, dominant males must remain with females at all times and have few opportunities to forage when defending females.

Dominant males choose females that are most likely to nest successfully. Females nesting in clusters are defended by higher-ranking males than those nesting in isolated sites vulnerable to birds of prey. Similarly, dominant males consort with significantly more females nesting on islands and around wasp nests than in sites accessible to mammals and snakes. Since dominant males can consort with only one female at a time, selectivity is rewarded. Indeed, some females nesting in extremely vulnerable sites are unconsorted by any male. This suggests that males expend time and energy defending only those females that have a reasonable chance of producing young and raising them to fledging stage.

For most males, dominance reaches its peak in the first one or two years of adulthood and then declines. All first-year adults are in the top half of the hierarchy. In each subsequent year, more and more males drop into the bottom half and by their sixth year, nearly all have become satellites. This is the reverse of the situation reported for birds such as cocks of the rock, black grouse, and birds of paradise, which congregate on leks, communal display grounds where mating will take place. In these leks, male dominance seems to either remain stable or increase with age.

The cacique trend toward declining dominance occurs within breeding seasons as well. Males that are dominant early in a season can be toppled by later-arriving males, many of which delay breeding until the season is well advanced. The rate at which males lose dominance varies enormously. Some males remain at the top of the hierarchy for several months, others last only a few weeks or even days. One male dropped from the number one to the number ten position in just three weeks. Another male at the same colony remained the top-ranked male for nine weeks during which he consorted with twenty consecutive females.

A case history that illustrates the changes in dominance that occur over the lifetime of a male is that of the male W/R. In W/R's first year of adulthood, he became the top-ranked male at two colonies. During the year, he consorted with eleven different females, and by season's end he was the second-ranked male in a large colony. Early in his second year of adulthood, W/R reclaimed the top position in the hierarchy of an island colony and had a record of seventeen uncontested consortships after two months. But by the middle of the nesting season, W/R had been bested by five males and consorted with only seven more females. At the end of the season, W/R was behaving like a satellite male. In his third year he once again rose to top position early in the season, but later dropped to third. When the season ended, W/R had consorted with only four females, twenty fewer than the previous year. In his fourth and fifth year of adulthood, W/R adopted satellite tac-

Mature males compete fiercely for dominance, which is usually determined by weight. High-ranking males may pair with as many as twenty-five females in a season. Right: A dominant male displays.
Luiz Claudio Marigo

tics. Therefore, over an average life span of five or six years, males are dominant only for brief periods. Counterparts of this process are found in several species of African antelope, including the impala and Uganda kob, in which males are also often not able to forage when defending females or to remain at the top of the hierarchy for more than a small fraction of their lives.

The primary correlative of declining dominance in caciques appears to be a loss of weight with age. After their first year of adulthood, dominant males drop an average of 4 percent of their weight each year, eventually losing the ability to overpower heavier males. Once males drop into the bottom half of the hierarchy and become satellites, weight stabilizes. The stresses of continual consorting—incurred only by dominants—may cause long-term weight loss. The reduced time available for feeding may irrevocably weaken these males.

Thus, males and females respond very differently to the constraints imposed by the scarcity of safe nest sites. Because older females form coalitions, they are relatively unaffected by weight loss with age. Males fight for females nesting in these safe sites, but the competition is so severe that each male has only a brief period of dominance before younger birds take over, and no male coalitions exist to compensate for the loss of weight with age. Older males therefore have few opportunities to breed successfully.

Caciques provide an especially clear case highlighting the relationship between predation, social behavior, mating systems, and sexual selection. Predation itself encourages colonial nesting and coalitions among females. The clustering of females in turn enables a few males to monopolize most of the females, which leads to a polygynous mating system. And competition among these males favors large size, which determines dominance. Within this framework, individual birds vary their tactics as they grow older, lose weight, and gain experience. Many other colonial birds, especially relatives of caciques, such as blackbirds and orioles, may eventually prove to have comparable social organizations. □

An Ill Wind

Sudden changes in intensity and direction, known as wind shear, blow no airplane any good

by James W. Wilson

On July 9, 1982, Pan Am flight 759 crashed during takeoff from New Orleans International Airport, killing 153 people. The National Transportation Safety Board determined that low-altitude *wind shear* was the probable cause. Three years later on August 2, 1985, Delta flight 191 crashed while landing in Dallas, Texas, killing 137. Headlines and newscasters again blamed wind shear. Even the blue ribbon panel assembled by the National Research Council after the New Orleans accident determined that thirty-two plane crashes and near crashes since 1964 were due to the phenomenon.

Wind shear, however, is an inclusive term. Meteorologists define it as any sudden change in wind speed, wind direction, or both. Wind shears are created by air flowing over rough terrain, by warm air currents rising from sun-heated ground, by the collision of air masses of different temperatures and moisture content, and by thunderstorms. Most have no effect on airborne planes. Some, referred to as turbulence, are felt as bumpiness. But a few actually bring about crashes. Even a casual observer knows that the wind varies frequently in intensity and direction and wind shear is a common occurrence.

The type of wind shear that imperils aircraft during takeoffs and landings needed greater definition. To this end, field experiments were recently conducted in Illinois and Colorado by scientists from the University of Chicago and the National Center for Atmospheric Research (NCAR) in Boulder. These experiments established that a wind shear called a microburst is responsible for aircraft accidents. Microbursts are produced when a rain shower or thunderstorm creates a current of rapidly downward moving air—a downdraft—that spreads out horizontally in a starburst pattern when it strikes the ground, just as water from a faucet spreads out when it hits a sink.

Meteorologists have long been aware that thunderstorms produce downdrafts that spread out horizontally in oval patterns at ground level, causing cool and sometimes violent winds. As far back as 1671, an Oxford fellow, R. Bohun, wrote *A Discourse Concerning the Origin and Properties of Wind* in which he described and sketched wind flows from clouds that suggest some awareness of the winds in a microburst. In 1946 and 1947 two University of Chicago meteorologists, Horace Byers and Roscoe Braham, documented the downdrafts caused by thunderstorms and the resultant horizontal winds near the ground. Until recently, however, even specialists did not understand that these airflows occurred in varying sizes and strengths and those of some diameters were especially hazardous for aircraft.

In April 1974, Theodore Fujita, a meteorologist also at the University of Chicago, who was studying aerial surveys of tornado damage, observed that small starburst damage patterns were caused by high-speed, small-scale, short-lived downdrafts. He named these starburst airflow patterns downbursts. Following an investigation of the Eastern Airlines crash at Kennedy International Airport in New York City on June 24, 1975, Fujita hypothesized that the crash probably took place when the airplane penetrated a downburst while landing. He later subdivided downbursts into several categories based on the size of their horizontal outflows. Downbursts having outflows with diameters of between 0.25 and 2.5 miles were called microbursts. This is the scale that we now know presents the greatest risk to aircraft.

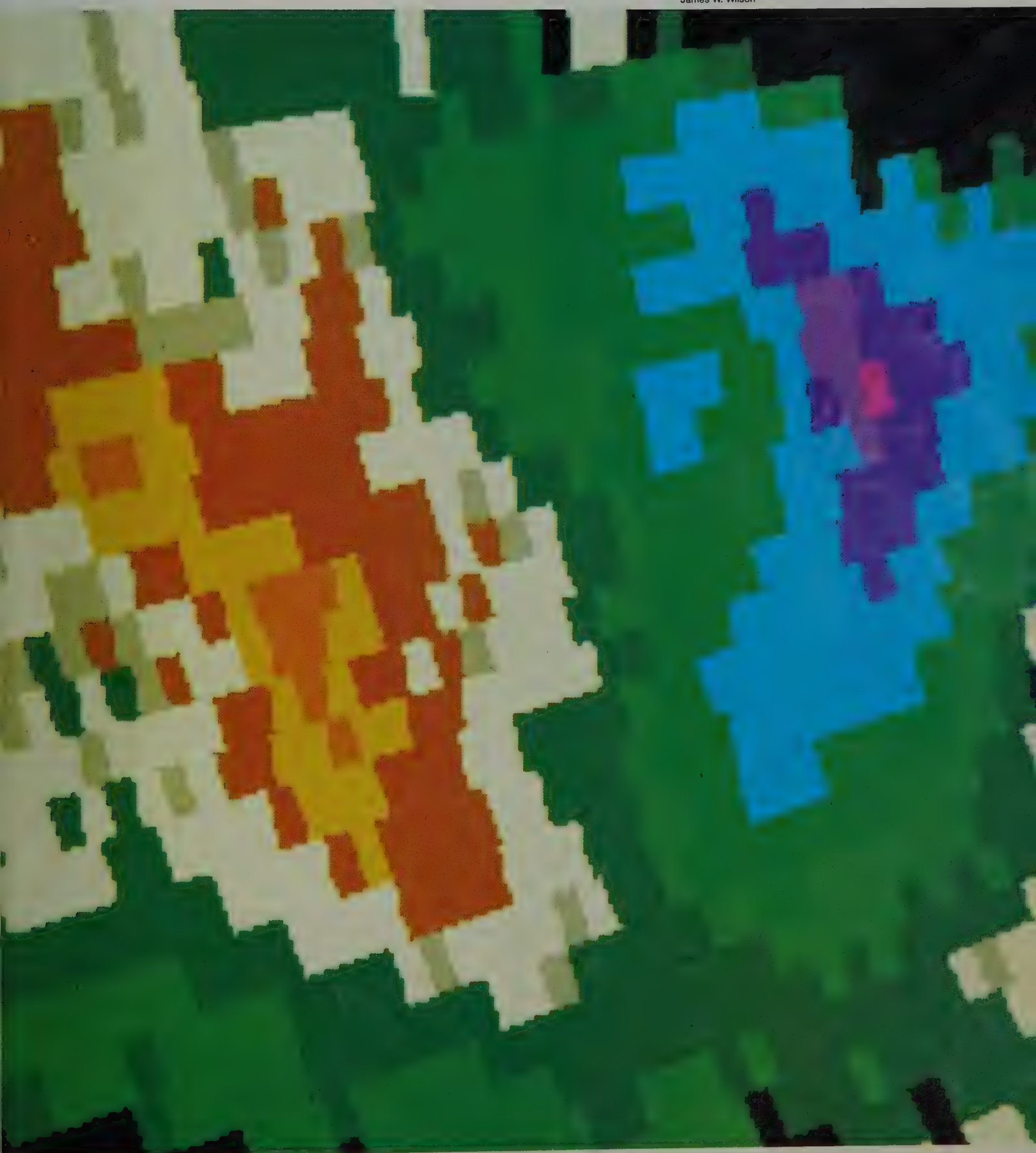
The first field program to study downbursts, called NIMROD (for Northern Illinois Meteorological Research on Downbursts), was conducted in Illinois in 1978 by investigators from the University of Chicago, the Illinois State Water Survey, and NCAR. Using Doppler weather radars that measure air motion within storms and a network of anemometers (instruments that measure wind speeds and direction), meteorologists were able for the first time to actually observe the airflow in a downburst. Before that, downbursts were largely hypothetical. Doppler radars measure the speed of targets moving toward or away from the radar antenna. They do this by measuring the frequency change between the transmitted microwave signal and the return signal after bouncing off a target. The frequency change is related to the speed of the target. This is the same principle employed by the police when they use Doppler radar to clock the speed of automobiles along a highway. In the case of weather radars, what is being clocked are raindrops, snowflakes, and even insects that are carried by the wind.

A second successful field experiment to investigate downbursts, called JAWS (for Joint Airport Weather Studies), was carried out in 1982 at Stapleton International Airport in Denver. This investigation was conducted jointly by Fujita, John McCarthy of NCAR, and me. We used three Doppler radar installations near the airport and recorded data on more than seventy microbursts. Analysis of our data indicated that the average microburst lasts only ten to twenty minutes, that the typical wind shear immediately following the downdraft hitting the ground is twenty-seven miles per hour, and that wind shear increases to fifty-six miles per hour from five to ten minutes after the initial impact and then decreases rapidly. Because of the small size and short lifetime of a microburst, existing wind-measuring systems at airports are frequently unable to detect microburst winds in time to warn aircraft. Low-Level Wind Shear Alert Systems have been installed at about 110 major airports across the country and are the only systems now in use that provide wind shear warnings. (The Doppler weather radars already in place are used primarily for weather research rather than for issuing alerts. But beginning in 1988, the United States government plans to begin installing a national network of Doppler weather radars to improve weather warnings.)

Wind shear endangers planes for the following reason. Once a plane enters a microburst, it encounters an increase in head winds radiating away from the center of the downdraft. This increase in head winds enhances the airflow over the plane's wings, causing the plane to pitch upward and forcing the pilot to compensate by reducing engine power. Then, as the plane passes through the downdraft center, the head wind rapidly decreases and becomes a tail wind, and the airflow

An experimental Doppler radar display at Stapleton International Airport in Denver shows wind shear in a microburst. The greens, blues, and purples indicate airflow toward the radar; the browns, away. The wind shear was fifty-eight miles per hour within a two-mile area from the brown center to the purple center.

James W. Wilson



Dry air (red arrows) penetrates a cloud formation, causing rain (green) or snow (blue) within the cloud to evaporate. Melting and additional evaporation may take place below the clouds as well. These processes create cold air (blue arrows) that will sink toward the ground in a fast-moving column. When this downdraft strikes the ground, it spreads outward in a starburst pattern known as a microburst. As an incoming plane reaches the edge of the microburst at point A, it encounters a head wind that can increase to twenty-five miles per hour between points A and B within eleven seconds. Only twelve seconds later, however, the head wind decreases to zero and becomes a tail wind, which in turn increases from zero to twenty-five miles per hour between points C and D. The plane is in greatest jeopardy as it passes through the center of the downdraft and begins to experience the increasing tail wind.

Susan M. Johnston

over the wings suddenly falls off, with a concomitant decrease in lift. Any additional loss of airspeed caused by the pilot reducing engine power and/or the downdraft of air pushing the plane toward the ground contributes further to this hazardous situation. With loss of speed, airflow over the wings may be reduced to the point at which the aircraft stalls and sinks rapidly toward the ground. If the plane is too close to the ground when this happens, there may not be enough time for the pilot to react and for the engines to regain sufficient power to compensate for the loss in airspeed. This is the likely sequence of events that caused the Pan Am plane to crash during takeoff at New Orleans International Airport. The wind shear in that accident was estimated at about fifty miles per hour within a distance of 1.5 miles, indicating that wind speed need not be extreme to pose a serious threat to aircraft. These conditions pose the same problems during takeoffs and landings.

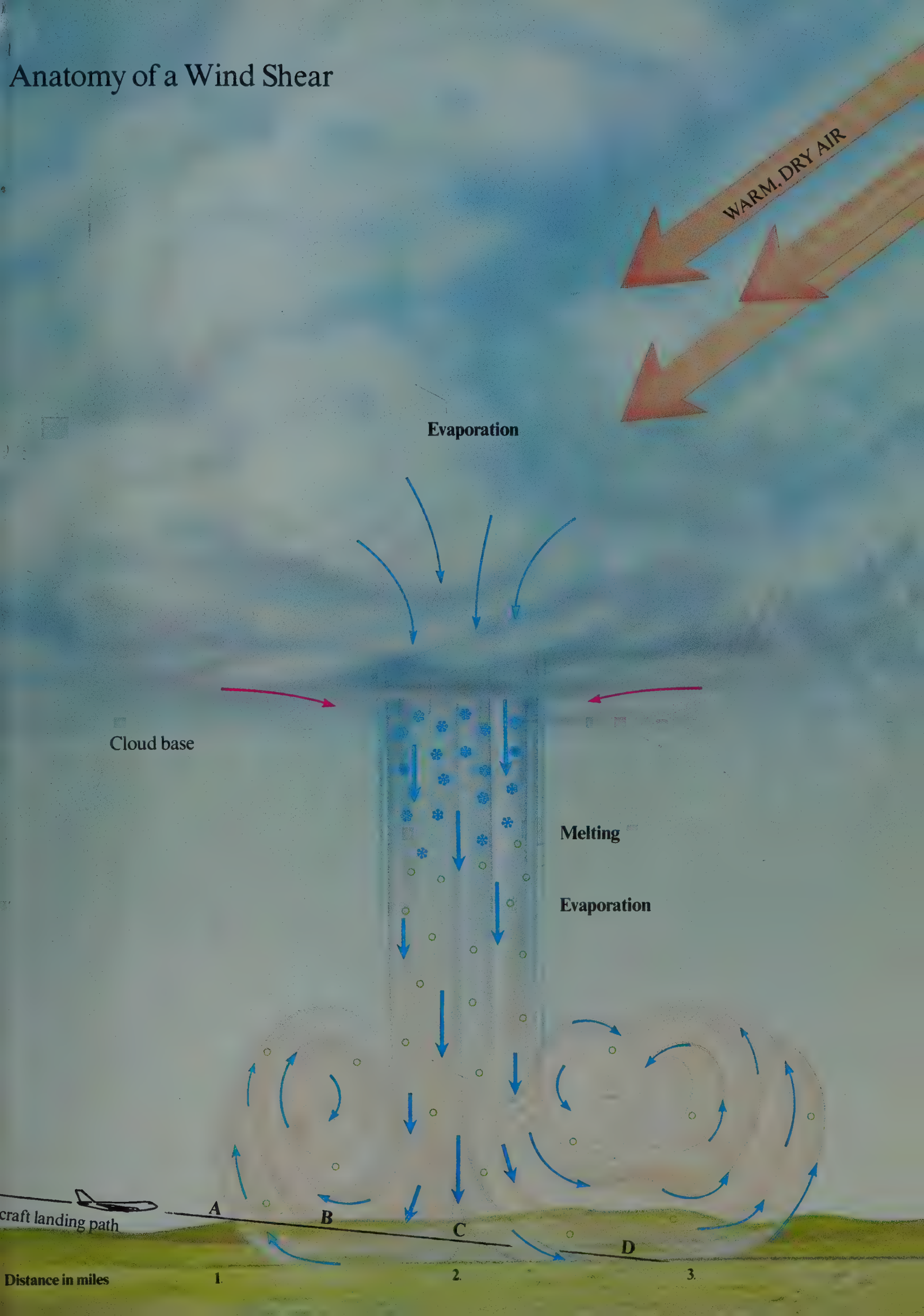
Research based on the JAWS data has shed light on the causes of a microburst. Before there can be a microburst wind shear a strong downdraft must reach the ground. This most commonly happens when a region of relatively cool air is generated, either within a cloud or below a cloud base. Such cool air masses are usually produced in two ways: the evaporation of rain or ice into dry air above ground level and the melting of ice as it falls to an altitude below the freezing level of the air. Because cold air is denser than warm air, it sinks toward the ground, producing the downdraft. Calculations based on computer models and on actual measurements show that downdrafts produced under these conditions can easily reach forty miles per hour. When a rapidly moving downward air column hits the ground, it has the potential of turning into horizontal winds moving in opposite directions at speeds of about forty miles per hour, thereby creating a strong wind shear.

Because precipitation is important in the production of a downdraft, microbursts are always associated with a precipitating cloud. The rain need not actually reach the ground, however. In the dry climates of the western states, rain may evaporate completely before it reaches ground level yet still produce a strong microburst. These above ground-level showers are a particular threat to aircraft because the precipitating cloud looks innocent and the pilot may be caught completely unaware. This is what happened on May 31, 1984, when a United Airlines jet was taking off from Denver's Stapleton Airport. The plane was departing during a seemingly benign shower in which only a few raindrops reached the ground. But just as the plane was lifting off the runway it penetrated a microburst and lost about twenty-five miles per hour of airspeed. The plane was only about ten feet off the ground and eleven hundred feet beyond the end of the runway, when the fuselage was punctured in three places by an antenna on the ground. The plane then moved out of the microburst and rapidly gained altitude but had to return to the airport because the holes in the fuselage made it impossible to pressurize the cabin. An almost certain disaster was narrowly averted because the pilot used a recently developed microburst flying procedure that involved pitching the plane up while moving at a low speed. However, this new procedure does not mean that pilots can now safely fly through microbursts. If the tail wind had been only slightly stronger, a crash would have been unavoidable.

As a result of this incident, the Federal Aviation Administration asked NCAR to conduct a microburst "real-time" forecast and warning service (that is, a system in which information about a microburst would be given immediately to those who need it) at Stapleton Airport for the remainder of the 1984 microburst season. (Microbursts are seasonal. They are associated with thunderstorms or rain showers and occur during spring and summer, or whenever such storms take place in a given region of the United States.) This experiment, called CLAWS (for Classify, Locate, and Avoid Wind Shear), depended primarily on meteorologists trained to identify and locate wind shear events on Doppler radar screens. This information was immediately transferred by radio to another meteorologist in the Stapleton Airport traffic control tower who passed the information on to the flight controllers who, in turn, notified pilots. This labor-intensive but very successful test demonstrated that Doppler radar could provide timely wind shear warnings. During the experiment, one pilot who was approaching for a landing credited a microburst advisory with saving his "aircraft from being forced into the ground short of the runway." In practice, the advisories would be transmitted directly, instead of indirectly, to the pilots.

The CLAWS project demonstrated that the technology exists to greatly reduce the risk of aviation accidents caused by wind shear. It also demonstrated that early advisories of wind shifts enable controllers to anticipate needed changes of runways, thereby decreasing delays and saving aircraft fuel. During the next five years a procedure is likely to evolve that will provide warnings of wind shears and other hazardous weather conditions to most major airports. This system will be based on new Doppler radars and will be capable of estimating wind speeds and direction every 200 to 300 feet within a fifty-mile radius. The primary task ahead is to develop improved computer models that will rapidly extract wind shear and weather information from radar and other instrument data and communicate it in a concise, informative manner to pilots as quickly as possible. □

Anatomy of a Wind Shear



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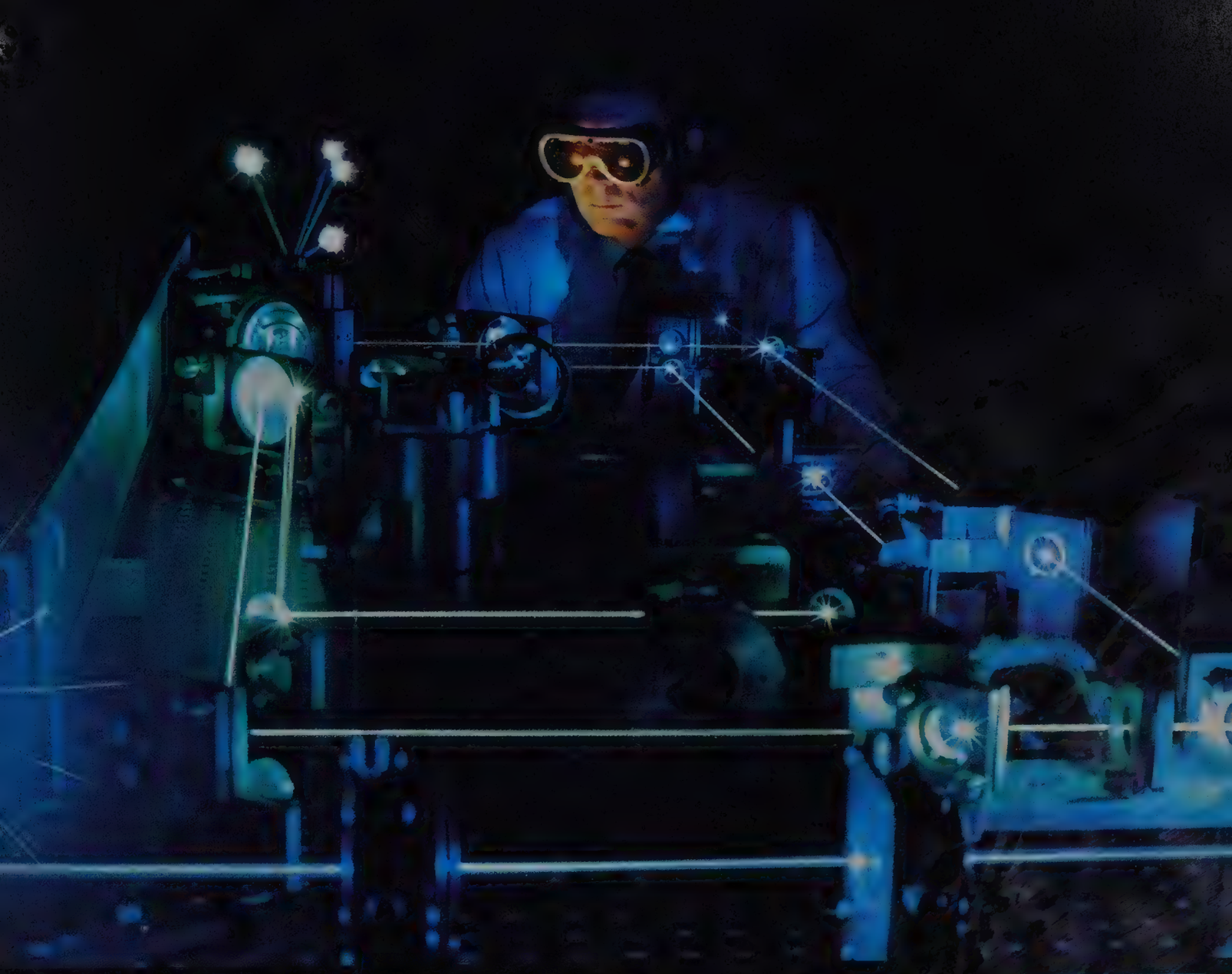

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The Paradox of the Great Irish Stags

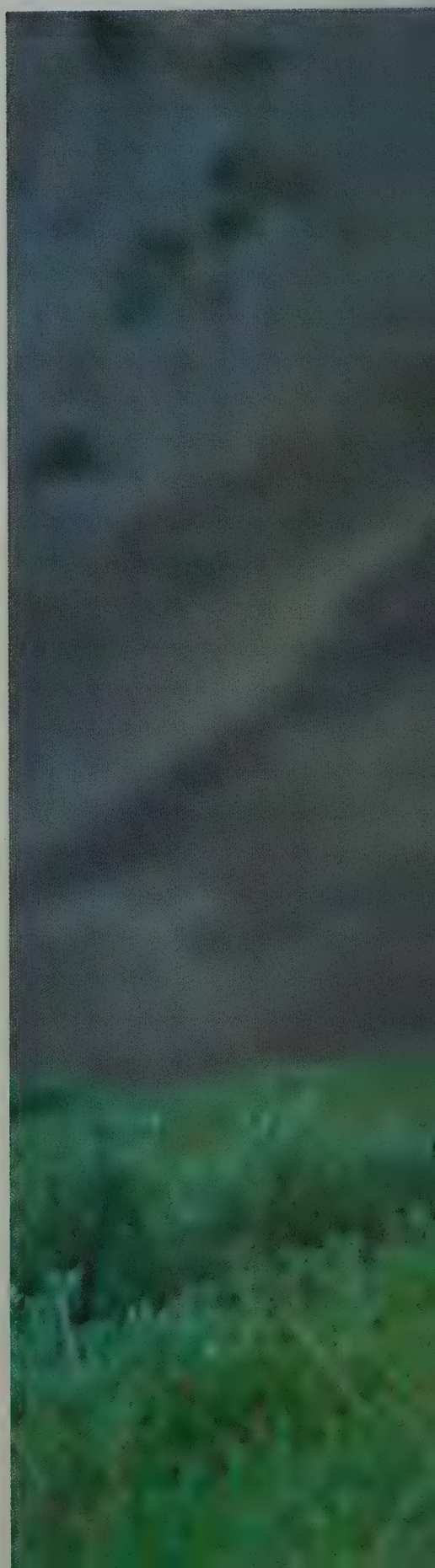
Were the huge antlers of the extinct Irish elk a sign that it was a swift and enduring runner?

by Valerius Geist

The huge antlers of the Irish elk have been a source of fascination ever since the fossil remains of the giant deer were found in Irish bog deposits in the seventeenth century. Growing from massive beams and spreading into broad palms with long, thick tines, the antlers are nevertheless graceful structures spanning from eight to eleven and one-half feet in large specimens and weighing between seventy-five and ninety-five pounds. Placed beside a set of large Alaskan moose antlers, the elk's antlers completely dwarf those of the moose, even though the moose's skull is likely to be larger. In body mass, Alaskan moose are the equal of Irish elk.

The mystery behind such huge antlers may now have been deciphered, and the question of why those of moose are smaller than those of the great elk or, for that matter, why antler size differs at all among deer species can now be answered. The solution came while reconstructing the ecology of the extinct giant, which appeared briefly in Ireland in the closing days of the last glaciation, some ten to eleven thousand years ago.

The Irish elk was neither an elk nor Irish, as evolutionary biologist Stephen Jay Gould has aptly pointed out. The term elk, strictly speaking, applies to moose, a member of the New World deer. The Irish elk was an Old World deer that belonged to a successful lineage of deer that spread across Europe and Asia during the middle and late Ice Ages, but failed to enter the eastern Siberian and Alaskan landmass and thus never appeared in America. The last species of these giant deer, *Megaceros giganteus,* vanished at the end of the last glaciation, as did many other large mammals. Its origin has been much disputed, but evidence has been steadily accumulating that *Megaceros* was a giant fallow deer adapted to the extremely fertile areas characteristic of the glacial periods. What *Megaceros* looked like is known not only from the complete skeletons found in Irish bogs but also from a number of sketches left in caves by our upper paleolithic ancestors. Light-colored, with some sharp body markings, *Megaceros* had a long, muscular neck without a mane, bell, or dewlap. Very large stags weighed as much as 1,600 pounds, and females averaged nearly a half ton.



Opposite page: A drawing based on cave paintings shows a young Irish elk's broad branching antlers. Selecting a diet of highly nutritious forage, caribou bulls, below, grow the largest antlers of all living deer, while female caribou produce the most concentrated milk. Caribou are also strong runners, as was the extinct Irish elk.

Stephen J. Krasemann/DRK Photo

Antlers are often a barometer of fluctuations in food supply. Large antlers, such as those of the red deer, left, indicate an animal's ability to find the richest food resources.
Arthus-Bertrand/Peter Arnold, Inc.

Although not the largest deer that ever lived—that honor goes to the broad-fronted moose—*Megaceros* is unsurpassed in the size of its antlers, the most massive of any deer, fossil or living. The antlers of young Irish elk stags were comparable in structure with those of mature mid-Pleistocene fallow deer. But in old *Megaceros* stags, an additional branching took place, so that their antlers had twice the points of their mid-Pleistocene relatives.

The Irish elk was unusual in another way: it was the most cursorial deer ever to evolve; that is, it was highly specialized as a speedy and enduring runner. Like other cursorial species—saiga antelope, gnu, Mongolian gazelle, eland, and buffalo—*Megaceros* was evolved to run on hard, level, unobstructed ground. In body shape, the giant elk closely resembled the eland, but had slightly longer legs and a longer neck. It had a cylindrical body, heavy shoulders, the slim and relatively short legs typical of speedy, flatland runners, and a large rib cage to hold a large heart and lungs. In relative capacity *Megaceros'*s chest exceeded that of moose by one-half and that of the red deer, an excellent runner, by about 20 percent.

The solution to the mystery of its huge antlers lies, paradoxically, in the giant deer's adaptation to running. Running with great speed and endurance is a means of evading predators and requires a large amount of space. For this trait to promote survival, the young must be as fleet-footed as their mothers soon after birth. Offspring must be born as large and as highly developed as possible and fed a supply of milk abundant enough in nutrients and energy to foster rapid growth to "survival size," thus shortening the vulnerable time period after birth. One would therefore expect to find, in living deer dependent on running, a single, highly developed offspring that shared neither womb nor milk with a sibling. In fact, cursorial young are on average the largest young born, much larger than the offspring of forest-adapted species.

To produce milk rich in nutrients and energy, the mother needs to select highly nutritious and digestible forage, and

George Herben/Alaska Photo

In body shape, the Irish elk closely resembled the African eland, below, another species highly specialized for endurance running. A herd of reindeer, right, race across a frozen lake—ice is their preferred escape terrain.

K & K Ammann; Bruce Coleman, Inc.

above all, she must be able to divert these nutrients and energy from body growth and maintenance to milk production. In males, the same genetic ability to divert nutrients means that more material is available for antler growth. Antler tissues are extremely sensitive to food intake and therefore are an excellent barometer not only of the year-to-year fluctuations in food supply but also of the male's ability to find the best food resources. A female choosing a male with relatively large antlers selects one with a hereditary endowment for superior foraging and for diverting nutrients and energy from body growth to antler production.

From a male's perspective, the female's choice is not a completely happy one. A male is best off putting all nutrient surplus into body growth. He then grows larger year by year and can dominate other males by sheer size and power. After all, antlers are throwaway organs. They are discarded each year, and so is the great investment in growing them.

What is the reverse of this evolutionary scenario? If the newborn young can be hidden from predators and raised in hiding to survivable size, the mother need not carry a single, huge fetus or produce the richest of milk or choose a mate with large

Female caribou with newborn calf, below. Since caribou rely on running to avoid predators, caribou offspring must be as fleet-footed as their mothers soon after birth. Consequently, they are born larger and more developed than forest-adapted species of deer.

Stephen J. Krasemann/DRK Photo

antlers. The males can sacrifice antler growth to an annual increase in body size—and fight it out for dominance. And the female, with smaller, slower-growing young, need not seek out the best forage.

If this hypothetical scenario is valid, then we would expect to find in deer a close correlation between the relative antler mass of males, the relative birth weight of young, and the percentage of milk solids in mother's milk. And that is just what one finds. Thus, male plains-dwelling cursorial savanna deer should have antlers much larger than those of forest species if the females have an increased energy investment in the young. We might also expect a jump in antler mass from forest- to plains-dwelling deer, more gradual and continual body growth in small-antlered deer, and leveling-off of body mass in large-antlered species. In fact, all of this is so. The relative size of calves and fawns increases from forest to savanna to steppe, but drops in desert, tundra, and alpine habitats. In short, newborn ungulates are largest where they are most readily seen by many predators.

As a rule, small ruminants require more digestible, richer, less fibrous forage than large ruminants. To maintain a constant temperature, a small animal must burn more energy because it has a larger surface area relative to its mass. Consequently, we find that small deer and antelope are very selective feeders, nibbling on such rich forage as shoots, buds, flowers, and seed heads. In deer, however, the general rule breaks down. Even though energy costs do go down with increasing body size, the costs for antler growth go up in a geometric fashion. The larger the stag, the more energy, protein, and minerals it requires to grow antlers.

We can calculate the quality of feed required to grow antlers of any size. A huge 1,500-pound *Megaceros* stag, growing one hundred pounds of antler mass in 120 days would require eighty-eight pounds a day of fresh forage (wet weight) so high in protein and minerals that only a very few plants could provide it. Regardless of his genetic endowment, a stag fed on the finest young meadow grass would only grow thirteen pounds of antlers because such grasses are low in phosphate, an important nutrient in growing bone. Even on good alfalfa a giant deer would only grow about forty-four pounds of antlers, because this renowned cattle feed contains far too few nutrients to support maximum antler growth in large-bodied deer. Only exceptionally nutritious forage will allow maximum antler growth. The young, and even the mature, leaves of several species of willow bushes provide such forage. Willows are abundant in deltas, on rich alluvial deposits, and in glacial environments along lakeshores, as well as on loess plains created downwind of glaciers and along glacial melt-off channels. Direct observations support the argument from bioenergetic theory: plant remains scraped from *Megaceros* teeth turned out to be willow.

The offspring of forest-dwelling deer species survive predators by hiding. The elk fawn, below, camouflaged among the forest grasses, counts on being overlooked by possible predators.

Pal Powell/Aperture

To achieve maximum new antler growth, males must be in a good nutritional state about one month before dropping their old antlers. We might therefore expect the *Megaceros* stags to have crowded into willow stands along shores and deltas in late winter and spring. Because lake ice provides a level, hard, unobstructed surface for running—avidly sought for purposes of escape by other cursorial species such as reindeer—we theorize that Irish elk escaped their predators, mainly wolves, in the same way. Because ice is fragile in late winter and early spring, this is a dangerous time for an ungulate choosing ice as escape terrain. Signs of antler shedding in many of the Irish elk skeletons indicate that a good many *Megaceros* bulls became victims of rotting ice. In addition, some of the remains were of stags that died in the shrubbery along the lakeshore or in deltas and whose bodies were moved into the lakes by gravity and water.

In spite of their nutritional needs, female ruminants, unlike males, give security, not food, the highest priority. Their remains are only rarely found near those of large males. The female *Megaceros* apparently avoided the water edges or areas

Stephen J. Krasemann/DRK Photo

The American moose, left, exploits the subarctic expanse of willows and birches. Visible to predators, moose have evolved superior running ability. Females, below, hide during the birth period and frequently produce more than one calf.

John Johnson/Alaska Photo

where willows would impede their ability to run. Handicapped by their young, they probably congregated in the uplands. Female remains of Irish elk are very rare, as are the remains of young bulls. This indicates that Irish elk segregated themselves in the manner of fallow deer, red deer, or wapiti; males three years and older formed groups away from females, young, and small males. Yearling Irish elk bulls, which probably remained with the females, are so rare in Irish lake deposits, that the juvenile stages of *Megaceros* antler development had to be described from fragmentary antlers found in continental deposits.

The hypothesis that giant deer were foliage feeders is also supported by their dentition, which is similar to that of moose, another great foliage feeder. The incisors of Irish elk, however, are broad and fan out, like those of wapiti, an indication that they were grazers during part of the year. Fallow deer, the close relative of the giant deer, are also foliage and forb feeders in spring and summer. They become grazers after satisfying the great nutrient demands of lactation, fattening, and body, antler, and hair growth. The flat loess plains, deltas, and melt-off channels inhabited by the giant deer, and where their fossil bones are concentrated, had plenty of sedge meadows.

Theories about *Megaceros* can be applied to living deer as well. Caribou, the most cursorial deer, bear one large and highly developed young, which closely follows its dam. The female produces the most concentrated milk of any living deer, and bulls grow the largest antlers. Caribou are specialized in selecting highly nutritious forage and choosing the most digestible of plant parts. For escape terrain they prefer frozen lakes.

The wapiti prefers more open spaces and grazing than the red deer and, in line with that preference, has a body shape more adapted to running. The wapiti's antlers, however, are relatively smaller. This appears to be a function of grazing; grasses—though fairly digestible, abundant, and free of toxic compounds—have lower concentrations of nutrients than forbs and foliage. As expected, wapiti milk is somewhat lower in milk solids than that of red deer, and wapiti young hide from predators.

The giant deer overlapped with moose in their Eurasian distribution, except in the eastern Siberian and Alaskan landmass. The moose selects highly nutritious forage and, like *Megaceros,* depends mostly on foliage. The ancestors of giant deer and of moose coexisted during the greater part of the Pleistocene, but both these foliage feeders adapted separately and ceased to be competitive. While *Megaceros* became adapted to running on hard, even, unobstructed ground, the moose became a superb, fast trotter, a specialist in rapid running over soft, uneven, obstructed ground. Moose can maneuver over uneven ground in a manner no horse can duplicate. Moose hide during the birth period and can give birth to two or even three small calves that the cow defends capably against predators and supplies with a fairly rich milk. Investment in newborns, however, is rather modest, and so is antler size, particularly in the European–west Siberian moose.

In the absence of giant deer in the eastern Siberian and Alaskan area, moose emerged to exploit the wide-open subarctic expanses of low willow and dwarf birch, as well as the sedge meadows and the deltas covered by low bushes. Here, they become visible to predators. We expect American moose to be tested by predators more often and, consequently, to evolve better running ability, larger young at birth, richer milk and, in the bulls, larger antlers and a plateau in body size. Wherever comparisons can be made with European moose, this is the case. American bulls have antlers twice as heavy as those of European moose with one additional radial branching of tines. American bulls reach a plateau in body size, while European bulls do not. We are not well informed about the reproductive investment of these two types of moose, but milk analysis indicates that American moose may have the richer milk.

In courtship, fallow deer have a striking antler display, a display so exaggerated and rhythmic that it borders on dance. Since the Irish elk was a fallow deer, and since social signals are very conservative in evolution (much more so than morphological characteristics), the Irish elk stag probably had a similar antler display. Caribou also have a fairly conspicuous antler display in courtship. (I have not seen comparable behavior in other deer.) Large antlers, then, appear to be display organs

Art Wolfe

The growth of large antlers is costly to a male deer because nutrients are diverted from body growth to produce organs that are discarded each year. Right: Large antlers, with the upper skull still attached, are from a dead caribou.

for enticing females, not weapons for intimidating opponents. But whether females of large-antlered species are indeed attracted to large-antlered males is still not known.

The antlers of the great Irish stag were hardly without adaptive value. They belong in the same category as peacock tails and the feathers of argus pheasants, which, ever since Darwin, have been suspected of having evolved as the result of female preference. In ruminants, selection for luxury organs by females appears to be confined to those species whose survival depends on running and a large investment in the care of its young. The large antlers of the Irish elk were blamed for its demise, weakening its body by drawing off so many nutrients and leading to death by drowning or by getting stuck in the forest. None of these speculations are valid. Although *Megaceros* antlers may appear heavy and unwieldy, they are no more so than the horns of mountain sheep and ibex. The great stag vanished along with other victims of a great environmental change—mammoths, woolly rhinos, horses, and saiga antelopes. *Megaceros*'s end came at a time of hardship for humans as well, noticeable in reduced body size. Neanderthal hunters had previously killed giant deer, and there is little doubt that upper paleolithic hunters also found ways to kill giant deer in times of need. In general, large mammals dwarfed in late glacial times, indicating a change in, and deterioration of, the environment. The Irish elk disappeared during those changing times. It was, after all, tied to large spaces of open, exceptionally fertile terrain that were characterized by a fairly long vegetative season. Because *Megaceros* could not withdraw into mountains, a reduction in the size and fertility of its habitat and the encroachment of forests would have caused its populations to dwindle rapidly. Hungry humans may have dispatched the last stragglers or, as the flatlands' vegetation changed to tall shrubs and trees, bears and wolves could have done as much. Only the giant deer's remains have survived to puzzle and haunt the imagination of humans, in a way few other species have done. □

Isaac Vasquez, a master weaver from the highland Mexican village of Teotitlán del Valle, adds powdered cochineal to a dye bath containing tejute *leaves, lime juice, and crushed limes.*
Gary N. Ross

The Bug in the Rug

Using ancient recipes, Mexican weavers brew the most permanent of scarlet dyes

by Gary N. Ross

In the southern state of Oaxaca, Mexico's three main mountain systems converge, forming one of the most convoluted and geologically unstable areas in North America. My Dodge pickup inched along what could have been the trail of an enormous serpent lost in the series of high ridges and deep gorges. Jumbled by frequent earth tremors, green, pink, and orange rocks shared the landscape with oversized cactuses and dwarfed trees papered with flaking red bark. There were four of us sandwiched in the vehicle. I was the American ethnobiologist who had returned to conclude a study of cochineal, a traditional red dye still prepared by a handful of Zapotec Indian artisans. My guide was Isaac Vasquez, a Zapotec master weaver from a highland village noted for its production of textiles and natural dyes. An American teen-ager living in Oaxaca, who had volunteered to compensate for my faltering Spanish, and a hitchhiking Mexican merchant rounded out the passenger list.

Our destination was the Pacific lowlands in the Isthmus of Tehuantepec. We were retracing a historic route. For centuries, Zapotec Indians from the plateau—ancestors of Isaac Vasquez—had braved this mountain bulwark to obtain the leaves of the *tejute*, or *hoja lisa*, tree (*Miconia argentea*), an essential ingredient in their cochineal dye. Distinguished as creative textile artisans and astute merchants, the Zapotecs held a virtual monopoly as suppliers of high-quality clothing in pre-Hispanic Mesoamerica, where numerous laws and customs regulated attire. On all occasions, from workaday labors to formal settings, even on battlefields, each individual wore fabrics that signaled his or her social status; dress was identity itself. Dyes were the principal basis of this hierarchy of clothing, and when it came to dyes, the Zapotecs reigned supreme. Human runners transported the treasures of *tejute* leaves, indigo bushes, murex snails, and other relatively mundane but necessary substances used to create the Zapotecs esteemed, long-lasting colors.

That well-trodden footpath provided the foundation for the serpentine ribbon of asphalt—now part of the Pan American Highway—that my pickup followed. Suddenly the undulations ceased and the road straightened. Isaac shouted upon spotting the first *tejute* tree. The species is medium-sized with an umbrella canopy and large, coarse leaves with whitish and heavily veined undersides. We crossed a barbed-wire fence into a pasture and quickly gathered enough leaves to fill six sacks, sufficient for a full year of cochineal dyeing. After a pause for refreshments, we set off on the return journey toward the temperate interior highlands.

My passion for cochineal began in 1978, when I visited the Zapotec village of Teotitlán del Valle. Most of the men in this community of more than 5,000 are weavers, and the village is famous throughout Mexico and among connoisseurs worldwide for its hand-loomed tapestries and rugs colored by fine natural dyes. I entered the showroom of Isaac Vasquez, then forty-three years old, whose work I had seen in an art gallery in San Antonio. I later learned that he was the most prestigious master weaver and dyer in the contemporary Zapotec culture. My host expounded in slow, deliberate Spanish—his second fluent language: "These colors can only be achieved with natural dyes, and only I and my cousin Alberto Vasquez, whom I taught, here in Teotitlán, are willing to take the time to prepare the dye bath as our ancestors did so long ago."

My eyes fell on the profusion of reds—crimson, scarlet, maroon, mauve, coral, pink, and lavender. Isaac noticed my wonderment. "Yes," he continued, "the reds are especially beautiful and my favorites, too." Then he added: "Did you know that we Zapotecs cultivated the dye-producing bug, the cochineal insect, long before the arrival of the Spaniards?" I had to admit my ignorance. The weaver walked to a small table, picked up a jar of what looked like small, gray seeds, and handed it to me. The seeds proved to be the dried bodies of thousands of tiny insects. Isaac explained that the dye is relatively simple to prepare. The brittle bugs "are ground into a powder and boiled in a water solution with lime juice and certain dried leaves."

I was hooked. Each day of the following week I returned to Teotitlán del Valle and sat for hours observing the various weavers at their looms. Isaac became impressed with my persistence. One afternoon he looked me directly in the eyes and asked: "Would you be interested in documenting the Zapotec method of dyeing?" He explained that he had gleaned the cochineal recipe from the village elders when he was still a boy, and that he had not divulged it to any outsider before. I was honored but told him that for the time being I had to return to Louisiana to resume my teaching and research duties.

During the next three years, I researched cochineal dye in my spare time. I learned that entomologists classify the dye insect in the order Homoptera, along with the more typical scale insects that plague many house and garden plants. The species name of the bug (now labeled *Dactylopius coccus*) has varied considerably throughout its illustrious past, primarily because there are two distinct forms. A small, wild cochineal lives on prickly pear and similar cactuses, which are found from Florida to Arizona and New Mexico, and south into the drier parts of Mexico and Central and South America. The slightly larger form, the cultivated, or domesticated, type, depends on human care for seasonal protection from the cold and thrives specifically on cactuses of the genus *Nopalea*, called nopal in Mexico. Both forms of the insect produce the brilliant red dye, but the domestic form, generally preferred because it is larger, is the only one that is commercially available.

Having retraced his ancestors' route to the Pacific lowlands, Isaac Vasquez collects the leaves of the tejute *tree, needed to make the cochineal dye permanent.*

Gary N. Ross

The nopal cactus is the principal host for the cochineal insect. The bugs secrete a cottony wax coating that protects them from desiccation and conceals them from predators.

Gary N. Ross

Maria Vasquez uses a stone grinder to convert dried cochineal insects into a powder. Carminic acid, a red pigment that pervades the insect's tissues and body fluids, constitutes about 10 percent of its dry body weight.

Gary N. Ross

The unusual natural histories of the two forms of the insect are virtually identical. The males undergo several complete metamorphoses as they develop into winged adults. Females, however, remain in a prolonged larval stage, never changing into winged adults but becoming sexually mature nonetheless—a process called neoteny.

The young females settle near their mother in groups of from four to ten and secrete from their abdomens a white, weblike material, which accumulates and becomes a cottony puff. This wax-based secretion, more profuse in the wild form, is an effective barrier against desiccation in the semiarid climate and a camouflage against potential predators such as birds, small rodents, and insect parasites. Within her protective cloak, each female is tethered to the cactus pad by a tubelike proboscis. Through this umbilical cord, she draws nutrients from the host plant for her entire life, up to three years. Within a few weeks of hatching, the female cochineal becomes bloated and sexually mature—a silvery, purplish black balloon about one-quarter inch long, similar to a fully gorged tick parasite.

The male cochineal remains diminutive and mobile. After a few weeks, he spins a cocoonlike structure and transforms himself into a tiny reddish brown, soft-bodied, delicate-winged flyer. Lacking mouthparts, the male is instinctively programmed for only one thing, sex, and that he pursues with relentless vigor, moving rapidly among the cactus pads and copulating with as many females as possible. The adult male dies after about a week.

The numerous eggs deposited by the female hatch immediately into tiny, reddish brown, six-legged specks. Those specks that will eventually become mature females usually remain on their home turf, puncturing the plant's cuticle, or wax layer, in order to get down to the business of feeding and reproducing. Inevitably, however, as the season progresses, the cactus-pad home and nursery becomes overpopulated. No matter. The newly born babies move easily on to greener pastures—an adjacent pad—and there set up new colonies. When all the home sites on a plant are taken, the tiny creatures cast their fates to the wind, the successful ones making a suitable landing on a fresh and uninhabited cactus.

The females are the source of the dye: a deep maroon pigment pervades their body fluids and tissues. Males may be minuscule sex machines, but females are equally potent. The maroon pigment, chemically identified in 1910 as carminic acid, is bitter and astringent to the taste and probably acts as a repellent to those few animals attempting to feast on the insects themselves or on their prickly cactus homes. It constitutes about 10 percent of the total dry weight of the insect—a high proportion compared with other insect pigments.

While the pigment may be repulsive to the palate, it is a feast for the eyes. There is, perhaps, an evolutionary basis for the color's fascination: red pervades the biological world as a color of warning and attraction, and it is the color of human blood. From paleolithic times, humans have sought out and used red pigments, beginning with such ready-to-use substances as ocher. With further experimentation they developed pigments that required some form of processing. Historians believe that cochineal ranks second only to indigo as the oldest processed natural coloring material.

Cochineal cultivation seems to have originated with the Zapotecs or with the Mixtecs, their Indian neighbors in the

Wool is boiled in the cochineal dye bath for up to two hours.

David Hiser; Aspen

Isaac Vasquez displays some skeins of wool dyed with cochineal. By using wools of different original shades, as well as by manipulating his dyeing techniques, Vasquez creates a varied spectrum for his textiles.

Gary N. Ross

nearby mountains. Cochineal husbandry was extensive and intensive in both these ancient cultures by the time the Aztecs first recorded its practice in the thirteenth century. The Aztecs had a special word for the insect—*nochezti*—as well as for two species of cactus on which it lived—*nopalnocheztli* and *nocheznopalli*. The town of Nochixtlán, a small Mixtec settlement in a severely eroded upland valley in northern Oaxaca, derives its name from Nocheztlán, an Aztec name meaning "the place where there is much cochineal." In the pictorial writing of the Aztecs, the community was identified by an ideograph of a pot containing nopal cactus with cochineal insects.

Nocheztlán was a tributary within the extensive Aztec Empire. (The Mixtecs own name for that settlement was Atoco, "in the place of the cochineal"; the Mixtec ideograph consisted of a mouth and a nopal cactus next to a seated man.) The warmongering Aztecs, who were constantly trying to broaden their sphere of control, did not always enslave or annihilate their captives. When the captured people could provide a valuable profit for the Aztec world, they were merely exploited by extracting a periodic tribute from them. Early Spanish chronicles indicate that the tribute exacted from the Oaxacan highland people by the Aztecs consisted of cochineal, other dyestuffs such as indigo, and finely woven textiles.

The arrival of the Spaniards in 1519 signaled a new era of cochineal production. The plundering foreigners had only been exposed to fabrics dyed red either from the roots of the madder plant or from the bodies of kermes, lac, or Saint John's blood, all insects that are related to each other and to the cochineal bug, but which produce less brilliant, more purplish shades of red. The Spaniards were instantly captivated by the intense scarlet cochineal dye, although they did not immediately recognize its origin as dried insects. Rather, they mistook the small, spherical bodies for seeds, which they appropriately termed *grana,* the Spanish word for seed (the scientific family name for the insect, Coccidae, also means seed). The *grana* was shipped from Mexico to Spain, where it met with instant success, becoming the rage of Europe. Next to gold, cochineal became the most desired commodity imported from New Spain, and in the seventeenth and eighteenth centuries, more was being produced in Mexico—principally in Oaxaca—than before the Spanish conquest. (A three-ship fleet that sank off Louisiana in 1766, currently under study and salvage, is supposed to have been carrying 599,522 pounds of cochineal.)

Spain could not maintain her monopoly on the carmine dye for long. In 1777, a French naturalist managed to enter Mexico secretly, travel on foot to Oaxaca (in itself a miracle), collect several cactus pads with their insects intact, then return to the coast and smuggle this living booty to Haiti. There, in that French protectorate, cultivation flourished for a number of years, providing a lucrative commerce for merchants in Paris.

During the next few years, through legitimate trade or by acts of subterfuge, other countries secured cochineal stocks and appropriate cactuses, and cultivation was taken up in Nicaragua, Colombia, Ecuador, Peru, Brazil, Portugal, the Canary Islands, and India. Because the international market for cochineal dyes collapsed following the invention of the first synthetic dyes in 1856, only Peru and the Canary Islands continue to produce the dye commercially for export.

As a red dye, cochineal has also had a

Below: Isaac Vasquez creates a tapestry on his loom. A work of this size may take a year to complete. Right: Isaac and his son Ernesto hold up a finished wall hanging dyed with natural dyes, predominantly cochineal.

Both photographs by David Hiser; Aspen

varied but limited use in the food, cosmetic, and pharmaceutical industries. Earlier in this century the dye colored such diverse commodities as pork sausage, pies, dried fish and shrimp, jams, jellies, ice cream, canned fruit, soft drinks, candies, cider, vinegar, medicinal pills, laboratory stains, lipstick and rouge, and the famed maraschino cherry. With the advent and spread of inexpensive synthetic coloring agents, cochineal gradually has been replaced. But the major red substitutes—red dye no. 2 and red dye no. 40—have not been problem free. Practically all such coal-tar dyes have been linked to one or more forms of cancer in laboratory animals and are therefore suspect for humans as well. Alarmed by this discovery, many manufacturers have once again turned their attention to the biological world for safe color additives. Cochineal, already approved by the Food and Drug Administration in the United States and time-proven safe, is now being reconsidered for more extensive use.

Embedded in this biogeographical saga is an ironic anecdote. Although cochineal production was common in southern Mexico, little or no knowledge of the insect and its aesthetic and economic potential reached the indigenous peoples of what is now the American Southwest. By the early sixteenth century, both the Pueblo and Navaho Indians had developed a sophisticated weaving culture. They did not have a strong red dye, however, relying instead on whatever reddish pigments they could draw from various barks, roots, and soils.

The Spanish soldiers who moved north from Mexico in the early 1800s brought with them colorful blankets from Spain, which they used for themselves and their horses. The blankets were made of *bayeta,* a commercially manufactured English flannel. Colored by the cochineal dye, the textiles fascinated the Southwest Indians, who parlayed and traded whatever they could to secure them. These people, principally Navahos, then unraveled the blankets, respun the threads, and rewove them into their own distinctive textiles.

Equipped with this background, I returned to Oaxaca, cochineal's ancient home, to document the insect's use as a textile dye. Isaac wasted no time on my initiation: the day after my arrival we undertook the arduous drive to the coastal lowlands. Then, while the *tejute* leaves we had collected dried in the sun for several days, my host, the "keeper of dye secrets," filled me in on his art.

"When I was twelve years old," Isaac began, "I was very curious to learn the dyeing methods of my ancestors—my heritage—and I gradually persuaded some of the old men to explain the process, which had been abandoned in the early 1900s when the more brilliant and less time-consuming synthetic, or aniline, dyes became available from Europe." He described how, after a short practice period, he was able to prepare a dye bath that produced the desired result. "With some additional experimentation," he added, "I was able to create shades that varied through the entire range of red."

Isaac tried to interest his fellow weavers in natural dyeing, but after a few attempts, their enthusiasm flagged. The task seemed too tiresome. Except for his cousin Alberto, they all reverted to the packaged anilines and their cookbook recipes. But it was not only the historical and cultural importance of using natural dyes that appealed to Isaac. With pride, he informed me that "unlike the colors from the European dyes, the cochineal hues are virtually permanent, since they resist fading from light and washing."

Isaac walked over to a cabinet against a far wall in his showroom. He returned with a casually folded piece of red woolen cloth. "Here is a skirt that has been in my family for more than three hundred years," he said, unfolding the piece. It had been scrubbed and beaten on rocks with harsh detergents and exposed to the intense tropical sun immeasurable times. Handing the piece to me, he exclaimed, "Just look at the brightness. It is almost as fresh as newly dyed wool. This is the advantage of cochineal."

The cloth was remarkably vibrant, although some of the threads were torn. I was impressed. Isaac smiled: "I think you are ready for cochineal. Let's dye!"

Most activities in a Zapotec household are concentrated in the central, open-air patio. The Vasquez patio has one small area reserved for dyeing, a shaded spot protected by a roof overhang. There a fifteen-gallon aluminum pot rested on a simple tripod of rocks. Stacked nearby was wood, gathered from the mountains above the village. First, the pot had to be filled with well water and the fire kindled to bring the contents to a boil. About two hours of heating were required, during which time Isaac and his wife, Maria, prepared the wool and ingredients for the eventual dye bath.

Isaac took three skeins of his wife's handspun woolen thread, about two pounds, and immersed them to soak in a tub of clear, cool water. As soon as the dye pot started steaming, three to four handfuls of the dried, crumbled *tejute* leaves were added. My guess is that the leaves contain oxalic acid, as do the leaves of many other members of the plant's family, Melastomataceae. This acid is recognized in the professional dye literature as a color intensifier and mordant for cochineal. A mordant is a substance, such as a metallic salt, that combines with an organic dye to form an insoluble colored compound, or "lake," in the fiber of the fabric.

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As the water continued to heat, Isaac plucked approximately eighty fresh limes from a tree that grew conveniently in the middle of his patio and squeezed out the acid juice by hand. I questioned Isaac about his use of citric acid: the citrus family of plants is considered a native of the Old World, having first entered Mexico during the early colonial period.

"The Zapotec's use of lime, crucial for the intense red color, dates only to the sixteenth century," Isaac responded. "Before then some alternative natural plant or soil acid must have been used." He sighed, and then added: "But my investigations have uncovered no written or spoken records; the secret remains in a world we have lost."

Isaac was confident that there had been an earlier intensifier, because he had seen samples of cochineal dye that survive on thirteenth-century Aztec manuscripts. The shades of red on such manuscripts could not have been produced by dyeing only with cochineal insects and *tejute* leaves. His ancestors had apparently experimented with the lime trees, however, which can be easily cultivated near home sites. As they welcomed the new acid into their repertoire, the original intensifier must have faded into obscurity.

While Isaac squeezed the lime, Maria prepared the cochineal insects for the dye. Since the supply in Mexico is now very limited, the weavers purchase their dried insects from Peru for about forty-seven dollars a pound, some 70,000 insects—a bargain since each bug must be tediously handpicked, swiftly killed by immersion in boiling water, which also dissolves its wax coating, and then dried in the sun for several weeks. As an emergency reserve, Isaac maintains a small colony of the insects on a grove of nopal cactus growing in his backyard.

Maria placed a *metate*, or "grinding stone," in front of her on the patio floor, and using a stone rolling pin, ground the dried bugs in much the same way she would grind corn for tortillas. Within thirty minutes, she had transformed one-half pound of the drab bugs into a colored powder. The grinding complete, Maria removed the powder and rinsed the *metate* with a cup of water, carefully collecting the runoff: cochineal is too valuable to waste.

When the water was boiling, Isaac added the powder and the salvaged dregs, causing the solution to become a dark red. He stirred the dye for a few minutes with a stick bearing the tenacious stains of past dye pots, then added the lime juice. The dye turned a brilliant red. Finally, the three skeins of wet woolen threads were

owered into the boiling caldron, and the olution was kept simmering for one to one nd one-half hours.

The acrid odor of hot acid permeated he air. My eyes watered as I stirred the ot; my tears caused my host to relieve me. With a smile he said: "My father told me that when he was a boy our entire village reeked of this odor. Practically everyone then prepared the cochineal dye several times each week." His smile faded as he reflected: "But now, only a handful recognize the source of the smell. What a catastrophe." I agreed.

Soon I understood why Isaac Vasquez is an internationally esteemed master of his craft. The wool's final color depends on many factors, including its initial color, ranging from white to various shades of gray, brown, and nearly black; the length of time the wool is in the dye bath; the amount of cochineal powder used; and the amount and type of lime used (Isaac uses the juice from fresh limes, but his cousin Alberto prefers whole dried limes). By manipulation of these factors, countless hues within the red spectrum can be created. Since the precise conditions are never recorded, however, only his years of experience and perceptive eye endow Isaac with a sensitive control of these natural colors, a control that can be admired and even envied, but never copied.

When Isaac gauged that the wool had reached the appropriate color, the skeins of thread were removed from the dye bath, shaken vigorously to dislodge the fragments of *tejute* leaves and limes, and hung on a nearby tree limb to cool and dry over night. The exhausted dye bath was then thrown out. When Isaac needs a relatively muted pastel, he will reuse the solution immediately for dyeing additional wools. He may also use it for overdyeing, a process in which threads previously dyed with one color are redyed with a second to achieve an uncommon hue. Because there is no refrigeration to protect the organic ingredients from spoiling, at day's end the solution in any case has the same fate. It is poured onto the bare ground of the patio.

The following day, we packed the pungent threads into my pickup and traveled the three miles of rocky road above the village to a small trickling stream. There Isaac washed the threads in a bucket of sudsy water (FAB is the product of choice) and rinsed them thoroughly in the flowing stream. The *tejute* leaves had done their job once again, the threads retained their intense red color. Back in the village, the skeins were suspended from a tree limb for two to three days of final drying before being transformed on the loom into works of art. □

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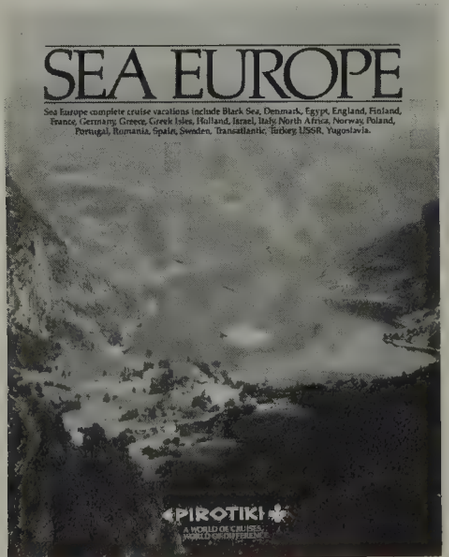
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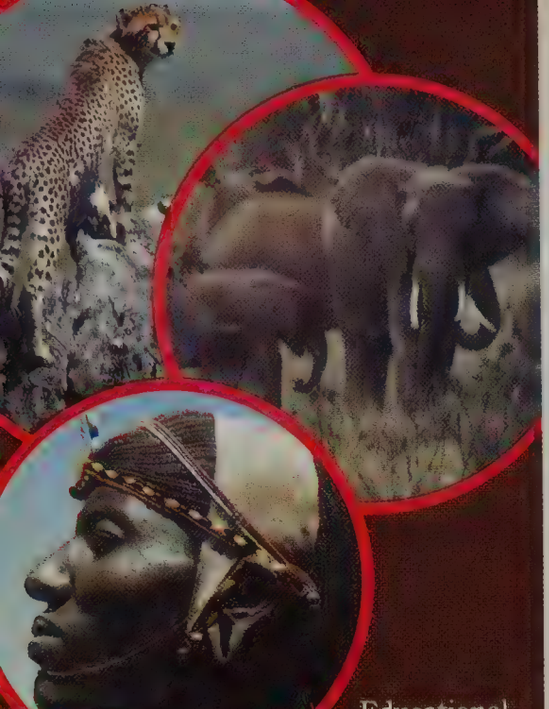

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Bounty of a Harsh and Meager Land

by Hugh H. Iltis

The preservation of genetic diversity in indigenous crops and ecosystems, of cultural diversity in indigenous peoples, and of a sustainable agriculture are the underlying themes of a remarkable new book by Gary Nabhan. Nabhan is a research associate at the University of Arizona's Office of Arid Lands Studies and cofounder of Native Seeds/Search, a nonprofit organization that maintains seed banks of southwestern plants, both cultivated and wild. The book is partly a serious consideration of desert natural history, ethnobotany, and environmental philosophy. It is also partly an anecdotal diary—sometimes charming and poetic, sometimes maddeningly cute—of the author's wide-ranging ethnobotanical explorations in the Sonoran Desert, which stretches south for 800 miles from Arizona and Southern California to nearly the tip of Baja California and the adjoining Mexican mainland. As a good ethnobotanist, he obtains much of his information from talking to people about their hard lives, uncertain crops, and wild animals and plants, all closely adapted to the vagaries of a stringent environment. Science aside, this is a book in praise of the desert and its people—a hymn to the wild beauty and diversity of the desert landscape, to the unsuspected usefulness and hidden ecological adaptation of its plants, and to the ingenuity of the cultural traditions by which the Indian tribes of the region, the Pima, Papago, Opata, Cocopa, Seri, and Yaqui, have learned to utilize "the botanical bounty of a harsh and meager land," on which most, to a large degree, still depend.

To illustrate the interaction of the human desert culture with desert plant ecology, Gary Nabhan has chosen an even dozen of the more than 425 edible wild species found in the Sonoran Desert. From the red-hot *chiltepines* (*Capsicum*) of Mexico to the *Washingtonia* fan palms of Southern California, each plant species "exemplifies a symbolic or ecological relationship that people of this region have had with plants through history." Although his choices are arbitrary, and important Mexican cultigens, such as maize and grain amaranths, are left out, the book makes fascinating reading for anyone interested in human ecology or ethnobotany. Like a botanical Vivaldi, Nabhan divides these plants among the four seasons; each chapter is prefaced by an original, stylized plate drawn by Nabhan's field companion, Paul Mirocha, a talented graphic designer with the University of Arizona. Each plate depicts the plant both in its natural habitat and in its relationship to man.

GATHERING THE DESERT, by Gary Paul Nabhan, *University of Arizona Press, $19.95; 210 pp., illus.*

Among the plants Nabhan has chosen is *Larrea tridentata,* the creosote bush, whose ancestors were dispersed by birds from its place of origin in southern South America. To the native people, the creosote bush is a veritable drugstore. Here, as elsewhere, Nabhan recounts anecdotes he has heard in his travels to juxtapose the wisdom of Indian medical, ethnobotanical, and agricultural traditions with the simplicity of their cultures. Creosote bush has been used by Indians to treat almost as many ailments as doctors treat with antibiotics. Be that as it may, the admittedly mild but unmistakable whiff of anti-intellectualism, evident in his potshots at the ignorance of scientists, botanists, and scholars, is disturbing (though many of Nabhan's targets may deserve it), and his lonely battle for an idiosyncratic cause (automatic respect for the nontechnical or primitive) is sometimes overplayed.

Washingtonia filifera palms are Nabhan's opening comment on the modern ecology of southeastern California. Although it is among the "four richest agricultural zones of the United States . . . the natural attributes that once attracted men of modest means to the area are now largely gone. The air is often dull gray in color, a stifling haze. Highway signs read-

ing 'Daylight Test Area' and 'Keep Headlights on for the Next 50 Miles' perplex unacquainted travelers. Surface water resources are overallocated. Groundwater overdraft per year has become so great that it would take decades without pumping to return the water table to its pre-1900 levels."

But even rigidly protected nature is not unaffected by land uses and abuses. "Northeast of Palm Springs in the Mohave Desert, the National Park Service created Joshua Tree National Monument to preserve palm and yucca stands . . . . To avoid desiccation of the tourist attraction, the wild *Washingtonia,* the National Park Service is running a pipeline up to the palms to keep them irrigated. With what? Pumped groundwater."

Another plant covered in the book is *Agave angustifolia,* the source of *mescal bacanora,* a powerful bootleg moonshine. As Nabhan explains, agave is pollinated by a bat, *Leptonycteris.* In recent years, however, the number of fertile seeds in the agave capsules has been decreasing, and a marked decrease in bat populations may be responsible. Southern Arizona caves that used to shelter hundreds of thousands of these pollinators, now shelter a few thousand at best. Zoologists have linked this decline in bat populations to pesticides, "which accumulate in bat breast milk and the young die of nerve disorders when the pesticides exceed a certain level." Even after the ban on DDT in Arizona, "*Leptonycteris* flocks continued to be exposed to this harmful chemical, since American manufacturers persisted in promoting its use in Latin American countries where these bats seasonally visit." (One of the very first acts of Ronald Reagan as president was to rescind President Carter's directive that any chemical banned on medical grounds in the United States is to be prohibited from being sold to other countries.) The other factor affecting these bat populations is the dramatic increase in the human population, which in Sonora has tripled since 1950. Evidently, the corresponding increase in

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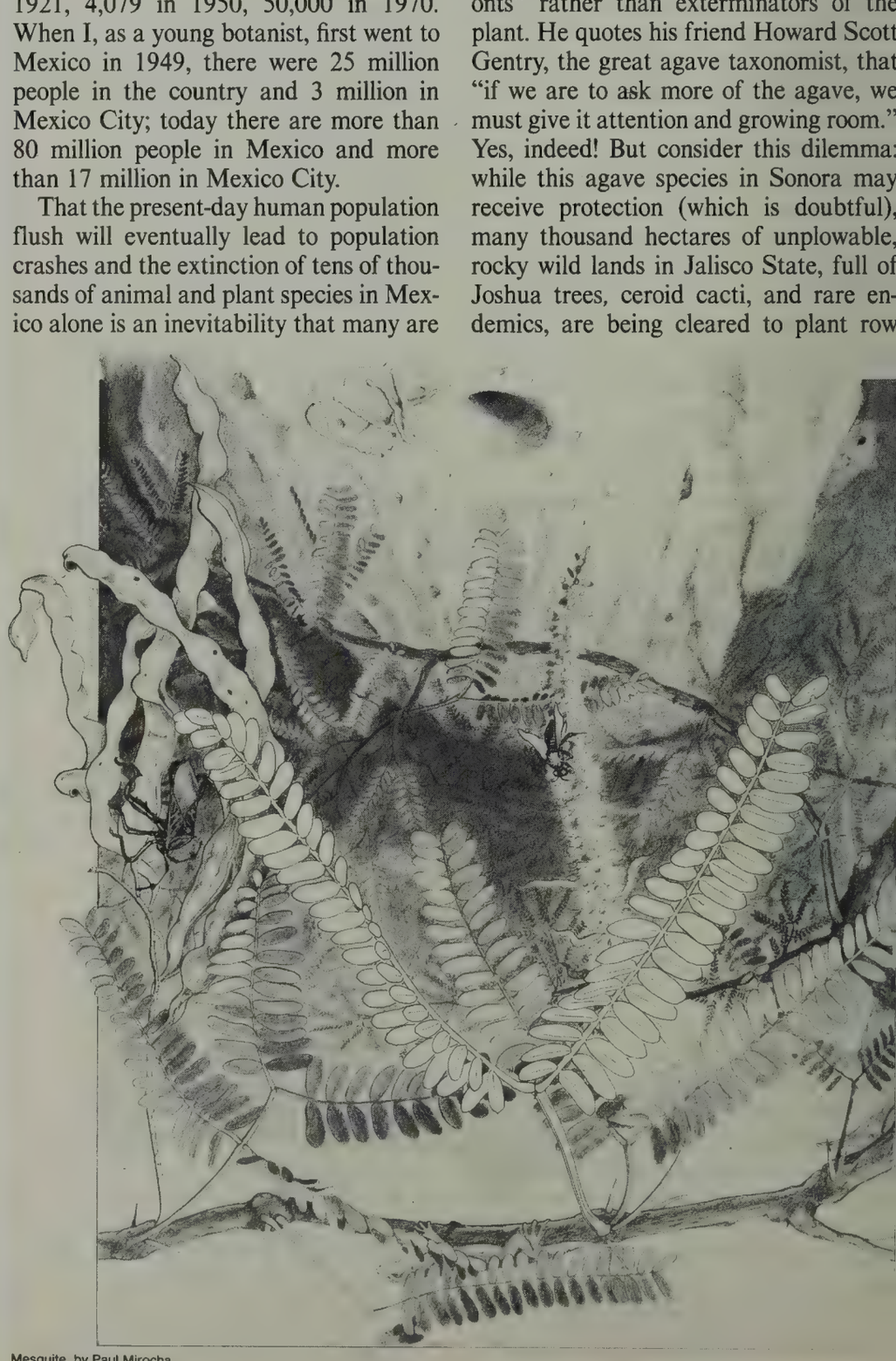
the number of drinkers has pushed the mescal distillers to overharvest wild agave stands and so destroy the major seasonal food source to which these migrating bats have been adapted by natural selection. No bat pollination, no agave seeds; no agave nectar, no bats!

If you consider, as Nabhan does, that a diligent *mescalero* has to cut down 1,600 agaves to distill the 300 or 400 gallons he needs to sell each year to make a living, and that there are one to two thousand or more such part-time harvesters in Sonora, more than half a million agaves may well be harvested in Sonora alone each year. Elsewhere, Nabhan cites the population figures for the U.S. border town of San Luis del Rio Colorado: 175 people in 1921, 4,079 in 1950, 50,000 in 1970. When I, as a young botanist, first went to Mexico in 1949, there were 25 million people in the country and 3 million in Mexico City; today there are more than 80 million people in Mexico and more than 17 million in Mexico City.

That the present-day human population flush will eventually lead to population crashes and the extinction of tens of thousands of animal and plant species in Mexico alone is an inevitability that many are unable to fathom, though the handwriting is on the wall all over the world: in Bangladesh, Ethiopia, Nigeria, Brazil, and yes, even in Mexico and the United States. As John Muir said, and Barry Commoner paraphrased, "Everything is connected to everything else": long-nosed bats to agaves to new babies to mescal drinkers to stock markets (and to biologists lamenting the loss of desert ecosystems and species).

Perhaps, says Gary Nabhan, "we are now too aloof, too impatient to wait for long-term rewards, too cocksure that we are the controllers of the world to be able to participate in a mutualistic relationship with agaves . . . ." He suggests that we place *Agave angustifolia* on the Endangered Species List and become "symbionts" rather than exterminators of the plant. He quotes his friend Howard Scott Gentry, the great agave taxonomist, that "if we are to ask more of the agave, we must give it attention and growing room." Yes, indeed! But consider this dilemma: while this agave species in Sonora may receive protection (which is doubtful), many thousand hectares of unplowable, rocky wild lands in Jalisco State, full of Joshua trees, ceroid cacti, and rare endemics, are being cleared to plant row



Mesquite, by Paul Mirocha

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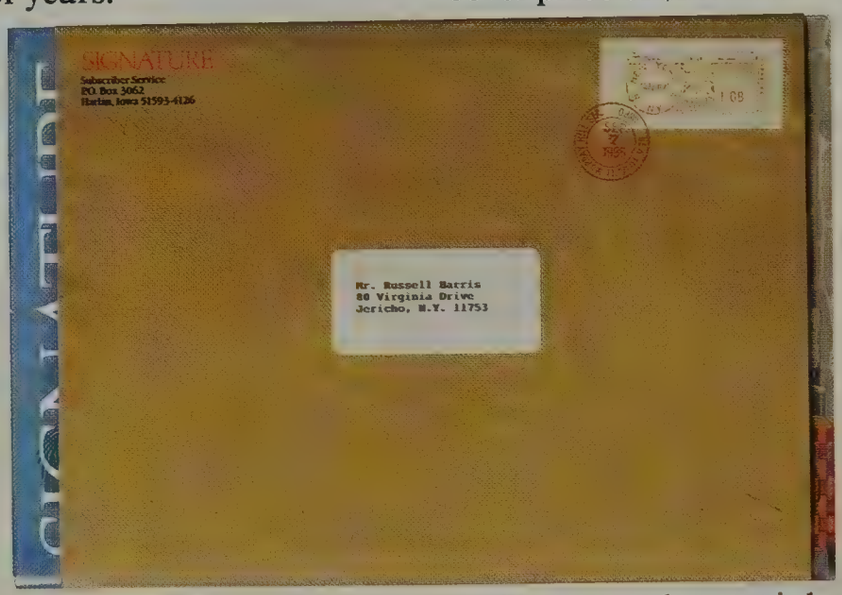

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upon row of agave. This agave is *A. tequilana*, harvested before flowering to make a mescal called tequila, much of which is exported to the United States.

Mesquite, a small tree of the legume genus *Prosopis*, offers birds shelter, mammals food, bees honey, and New York steakhouses smoky-flavored steaks. "Even though the charcoal gives off little of the mesquite wood scent, the whole pitch is lucrative as hell." More important, mesquite is a key species in the desert's web of life. Of the solitary bees alone, fully sixty-four species visit mesquite flowers.

Organ-pipe cactus, *Stenocereus thurberi*, another key species, is pollinated by one bat, and its seeds, immersed in juicy pulp, are dispersed by another. At the very edge of its range in Arizona, we have a national monument for it, but it grows best in Mexico. Dot distribution maps of this and other species could easily have been added or at least referenced to those already published. These would help to complete the ecological picture and give it biogeographic context, for surely, one map is worth a thousand words.

Amaranthus palmeri greens, the meat of the poor people; tepary beans (*Phaseolus acutifolius*), representing agriculture at its very arid limits; the wild *chiltepines*, or bird peppers, the red-hot mothers of chile peppers, *Capsicum annuum* var. *aviculare*, are just a few more of the plants covered here. A twenty-one-page bibliographic essay (but no badly needed glossary) and a two and one-half page abbreviated index, as inadequate as it is inaccurate, ends this otherwise beautifully produced book.

Let me make two final observations. First, the bibliographic essay is unbalanced and idiosyncratic. How can an ethno*botany* book dealing with the Sonoran Desert, which mentions scores of major and minor (often insignificant) studies by the author and his friends, fail to mention *any* of the modern works on this region? Not Shreve and Wiggins' magisterial *Flora and Vegetation of the Sonoran Desert*, not Kearney and Peebles' thoroughly revised *Arizona Flora*, or Wiggins's masterful *Flora of Baja California*, all major and truly monumental works without which any ethnobotanist or amateur would be adrift in a sea of taxonomic confusion. Similarly, how can one discuss *Amaranthus* without at least mentioning the ethnobotanical studies of Jonathan Sauer, or Sonoran cactus ethnobotany without citing the fine study by Frank Crosswhite on the saguaro (*Carnegiea gigantea*), or any number of his other major papers on Indian tribal ethnobotany.

Secondly, the last chapter points to the great paradox any conservation-oriented botanist working with cultivated plants is faced with sooner or later. (I have faced it myself in my own work with wild corn, the teosintes.) There is a conflict between the desire to preserve ecosystems and the need to use them: what do you do, what should you do, when your own discoveries will encourage the destruction of more wild land to grow more food on the very ecosystem you love and wish to preserve? The author pleads for preservation of primitive people and their customs, favors germ plasm diversity of cultivars and of wild plants, and then, in his very last example, yields to temptation. Nabhan came upon the pioneering discoveries of Larry Curtis, who found that the gigantic 100-pound roots of the buffalo gourd (*Cucurbita foetidissima*) produced a rich supply of starch (53 percent) and that its seeds could be bred to yield a high-grade polyunsaturated oil. Nabhan, alas, is quickly seduced by a grand vision, a whole new world of deserts made fruitful! "Curtis and followers imagined commercial production of desert gourds based on three major products: a cooking oil, a protein-rich seedmeal feed left after oil extraction, an industrial starch from the root to be used in food thickeners, cleansers, and other specialized products." Improved hybrids are now available, and "since 1979, buffalo gourd has advanced as an experimental crop in Mexico and the United States, with the field trials attempted in countries such as Australia as well." After listing several wonderful attributes recently discovered, Nabhan ecstatically predicts that this species "could have a future economic niche in semiarid areas receiving ten inches of rainfall or more." A second species, the finger-leaved coyote-gourd, *Cucurbita digitata*, is even more adaptable: "Capable of long-term survival in extremely arid regions receiving less than four inches of rainfall, [it] can probably produce economic crops with less irrigation, particularly in hot coastal deserts where buffalo gourd barely survives." He laments the lack of commercial interest in establishing plantations, but hopes that these gourds' insecticidal promise—as trap crops they attract luperine beetles—may push them into commercial cultivation.

But what is going on here? Are we now to lose the world's coastal deserts? (My mind wanders to the silent immensity of the Peruvian coastal desert, with its flower-covered *lomas*, and I am revolted by the vision of miles upon miles of the "most stinking gourd, *C. foetidissima*.") How can Nabhan advocate preservation

desert culture and diversity and at the me time beat the drum for a new crop at could wipe out the coastal desert alto-ther. You can't have it both ways.

Evidently Nabhan's deep environmen-l concerns, and they seem genuine ough, do not prevent him from present-g this or that new "botanical fix," which, r better or for worse, will lead to the gricultural use and eventual destruction such now unused lands. Shouldn't we ope instead that the buffalo gourd will rove to be a feasible crop on Arizona otton land, where eight to ten inches of in per year would allow it to grow *with-ut* using scarce, pumped ground water, ut a failure in coastal deserts and else-here where the land should never be ultivated in the first place. I do not wish be harsh on the author. I know how it is, aving been a party to the discovery of *ea diploperennis,* the perennial wild orn endemic to *one* mountain in Mexico. Valter Sullivan propelled the discovery to he front page of the *New York Times* ith promises of a perennial corn that ould feed the world and which, it has rned out, has immense immunity to all orts of corn diseases. The paradox is eightened when such publicity is a way often the only way) to obtain money for reservation of a specific site. (Such was he case recently with the Mexican gov-rnment's purchase of a part of the Sierra e Manantlán to which *Z. diploperennis* is ndemic.)

I do not have easy answers. I do know, owever, that we should be careful to save he deserts in all their loveliness and bio-ogical complexity, although most plan-ers, movers and shakers, and developers onsider them nothing but expendable, hrowaway ecosystems—empty waste-ands without value, without grace. We hall never solve world hunger by growing nore food or plowing up more deserts, nly by growing fewer people. The earth an't provide unlimited land, unlimited growth, unlimited technology!

In the deserts of the world, agricultural exploitation may well find a new last stand. But what then? After all the deserts are green and an additional four billion people are fed, what then? And when no more deserts are left to plow? When no more desert people are left to care? Gary Nabhan's book, with all its faults, is a splendid way to learn to love—and save—the deserts.

Hugh H. Iltis is a professor of botany and the director of the Herbarium at the University of Wisconsin-Madison. Iltis specializes in the evolution of corn and its relatives.

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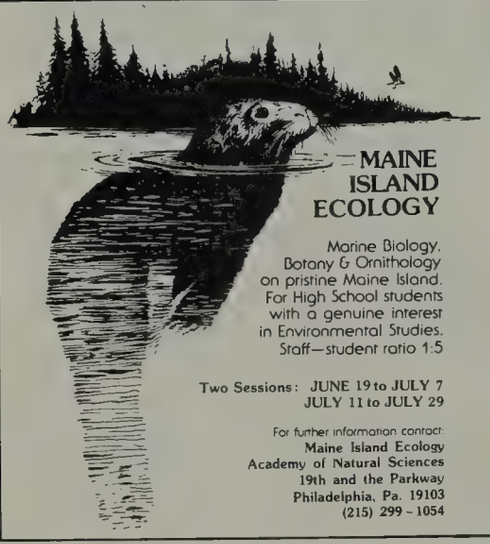

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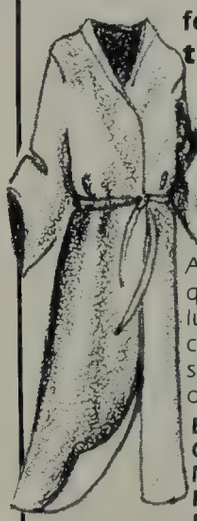

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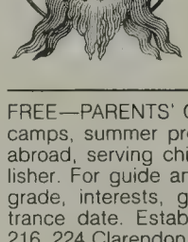

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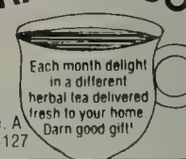

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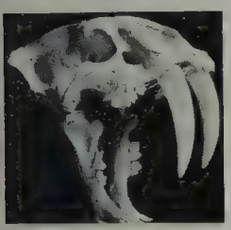

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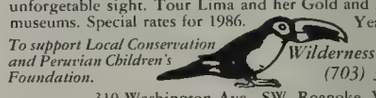

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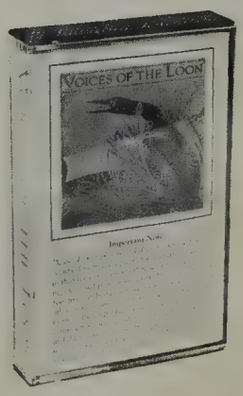

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The Jewel in the Satellite

An instrument aboard a little-known orbiting spacecraft has provided valuable information about the solar corona

by Stephen P. Maran

In February 1979, a relatively unpublicized Air Force satellite named *P78-1* was launched from the Western Test Range at Vandenberg Air Force Base in California. Among the instruments it carried was a coronagraph known as Solwind. A coronagraph is a sun-watching telescope equipped with an occulter, a small round disk or other object that blocks out the sun's brilliant surface (photosphere), thereby creating an artificial total solar eclipse. This allows astronomers to study the sun's faint outer atmosphere, or corona, the source of the solar wind—the magnetized, electrified gas that blows out from the sun toward the earth and other planets.

Although some solar physicists felt that Solwind was obsolete even before it was launched, all now agree it was a valuable resource and that during the six and a half years of its existence, the thousands of coronal images it sent back to the earth made a major contribution to science.

There have, in fact, been coronagraphs in space since the early 1970s. On the ground, the daytime sky is lit a bright blue by sunlight scattered by air molecules, causing severe interference with photographic studies of the solar corona, except during total eclipses of the sun. In space, however, the sky is black and a coronagraph can obtain superb photographs of the corona. The words "can obtain" are used advisedly because the first satellite-borne coronagraph, a device launched on the NASA satellite *OSO-7* (for Orbiting Solar Observatory No. 7) in September 1971, sent back relatively crude images. They were good enough, however, to enable astronomers at the Naval Research Laboratory in Washington, D.C., who built the *OSO-7* coronagraph, to discover so-called solar bubbles. These are coronal mass ejections, a previously unknown phenomenon. A solar bubble is a huge, round, magnetized structure of as much as one billion tons or more of electrified gas, which is hurled out of the solar corona and into interplanetary space at speeds of up to four million miles per hour. These bubbles usually follow the eruption of solar flares or other disturbances at a lower altitude of the sun's atmosphere.

With the advent of *OSO-7* and space-borne coronagraphs, the number of ground-based scientific observations of eclipses began to decline. Although some astronomers still conduct experiments or observations of total eclipses at terrestrial sites, especially when searching for changes in the diameter of the sun, this activity has largely been superseded by advances in space astronomy.

Pictures of coronal mass ejections that were superior to those of 1971 were obtained in 1973 and 1974. These were made on photographic film by a new model coronagraph built at the High Altitude Observatory of the National Center for Atmospheric Research in Boulder, Colorado, and put into orbit aboard the manned spacecraft *Skylab*. In late December 1973, when Comet Kohoutek made its closest approach to the sun, only the *Skylab* astronauts could see the comet, but it was photographed through the sun's corona by both the *OSO-7* and *Skylab* coronagraphs. When I examined those photographs in 1974, I never dreamed that one day a coronagraph would become a prime tool for the discovery of new comets. Yet that was to occur with Solwind.

The most advanced coronagraph put into space, also built by the High Altitude Observatory, was launched aboard NASA's Solar Maximum Mission in February 1980. There is always intense competition for payload space aboard a NASA satellite and *Solar Max* (as this craft is familiarly known) was no exception. The group from the High Altitude Observatory won that competition and thus the right to place their new and larger coronagraph aboard *Solar Max*. To continue their own work, the Naval Research Laboratory group managed to transfer leftover *OSO-7* spacecraft and instrument hardware, in effect, high-tech spare parts, from NASA to the Department of Defense. From those spare parts, and with the addition of other instruments, the Air Force's *P78-1* and the Naval Research Laboratory's Solwind were born.

Solwind's design was based on the technologies of the late 1960s. The photographs that it obtained of the solar corona were less sharp than those from *Solar Max* and, in my opinion and that of some other critics, less spectacular. Further, the *Solar Max* coronagraph was equipped with a set of scientifically designed filters through which its pictures were taken. That's why many astronomers, myself among them, did not expect a major set of coronal breakthroughs to come from Solwind. There was, however, at least one characteristic in Solwind's favor. Although its coronal pictures were not as detailed as those from *Solar Max,* Solwind regularly monitored a much larger region of the corona, a ring-shaped zone centered on the sun and extending from a radius of 2.5 times that of the sun out to a distance of about ten solar radii. The region of the corona monitored by *Solar Max,* in contrast, extends only from 1.6 to 6 solar radii, reaching to 6 radii only in the corners of the rectangular images.

A greater and unexpected advantage came when the *Solar Max* coronagraph suffered a major electronic failure on September 23, 1980, and ceased to operate. For three and one-half years thereafter,

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Solwind was the only working coronagraph in space. Even though its pictures were not the very best, its electronic camera provided our only regular source of coronal photographs from the date of the *Solar Max* coronagraph failure until April 11, 1984, when astronauts from the space shuttle *Challenger* repaired the *Solar Max* coronagraph in space.

Using the long series of uninterrupted coronal photographs from Solwind, Naval Research Laboratory scientists, led by Donald J. Michels and Neil R. Sheeley, Jr., made an almost equally uninterrupted series of findings. Most impressive, to me, was the discovery that small comets are raining down onto the sun (see "Sun-grazing Comets," *Natural History,* March 1983). As of early December 1985, when I wrote this column, five such comets had been found in the Solwind photographs. Solar physicists, however, cite other outstanding findings made by Solwind. In a recent letter to me, Robert M. MacQueen, director of the High Altitude Observatory, who is both a coronagraph developer and a solar expert, wrote that by using Solwind's long series of coronal photographs, we can "examine the general properties of coronal mass ejections, such as their distributions in mass, speed, [and] latitude" in order to understand what they are and how they fit in with other events on the sun.

The most important Solwind findings, according to MacQueen, include the identification of "halo transients"—the coronal mass ejections that are emitted directly from the sun toward the earth. In contrast, nearly all other observed solar bubbles were emitted roughly at right angles to the line of sight from the earth to the sun. The design of any coronagraph tends to favor recording events directed at right angles to the earth–sun line. That is because the coronagraph's occulting disk covers up the earth-directed ejections along with the underlying bright solar surface. Matter ejected at right angles to the sun–earth line becomes visible in a coronagraph as soon as it travels past the border of the instrumental occulting disk. An earth-directed solar bubble, in contrast, must *expand* to a greater apparent size than the occulting disk in order to become visible in a coronagraph. Usually, such expansion will render the bubble too thin and faint to be photographed, like a smoke ring that's minutes rather than seconds old. But among the hundreds of such ejections photographed by Solwind, a few earth-directed gas blobs, including one observed on November 27, 1979, were bright enough to remain detectable after great expansion.

Another important Solwind observation was the photographing of a high-latitude solar bubble ejected from the north polar region of the sun. No such event had been recorded by the earlier coronagraphs on *OSO-7* and *Skylab*, leaving open the possibility that none really occur.

Timing was particularly important in the Solwind observations of solar bubbles. The *P78-1* satellite was launched near the peak of the eleven-year sunspot cycle, while the *OSO-7* and *Skylab* coronagraphs observed the sun only during the declining (postmaximum) phase of the previous eleven-year cycle. Thus, by comparing their observations with those made by the earlier instruments, the Solwind experimenters were able to correlate the nature of solar bubbles with the phases of the sunspot cycle. The Michels-Sheeley group of the Naval Research Laboratory found that solar bubbles that are ejected near the sunspot maximum seem to occur more frequently and over a wider range of solar latitudes than those that occur in the declining phase of the sunspot cycle.

A particularly important contribution of the Solwind studies was the correlation of the solar bubbles observed by Solwind with interplanetary magnetic clouds and shock waves that were detected by interplanetary space probes as they swept out through the solar system. From those studies, it has been possible to link the magnetic clouds (invisible, large magnetized structures in the solar wind) found in interplanetary space with specific bubbles ejected from the solar corona. The same was true for the shock waves—disturbances traveling through the solar wind at speeds above the speed of sound in that medium.

In one case a magnetic cloud that swept past the German-American space probe *Helios 1* at 290 miles per second in June of 1980, when that probe was 50 million miles from the sun and about 90° west of the earth–sun line, was found to be correlated with a loop-shaped coronal mass ejection that Solwind had observed two days earlier. This helped to confirm that as the solar bubbles dim and expand into space, they stimulate or themselves become magnetic clouds.

Studies of interplanetary shock waves recorded by space probes and of the solar bubbles photographed by Solwind have shown that shock waves associated with those bubbles last longer and travel farther into space than shock waves that arise from other causes. Comparison of Solwind observations with measurements by *Helios 1* also shows that the solar bubbles may leave the sun at much lower speeds than those of the associated shocks as measured far from the sun. There are varying interpretations of this finding, so that further observations and analysis may be necessary to clear it up.

Unfortunately any future observations will have to come from the *Solar Max* coronagraph or from another coronagraph on a future satellite. On September 13, 1985, the Air Force made a direct hit on Solwind's carrier, the *P78-1* satellite, in a highly successful antisatellite missile test, thereby bringing Solwind's steady six and a half years of solar monitoring to a sudden end.

The space junk now orbiting the earth includes more than 100 observable fragments of *P78-1*, presumably including some parts of the once underrated coronagraph that we now recognize as the jewel in the satellite. But the thousands of coronal photographs Solwind obtained, which are stored on computer tape, remain under examination and may contain many more surprises.

Stephen P. Maran is a senior staff scientist in the Laboratory for Astronomy and Solar Physics at NASA's Goddard Space Flight Center in Greenbelt, Maryland. The opinions expressed here are his own.

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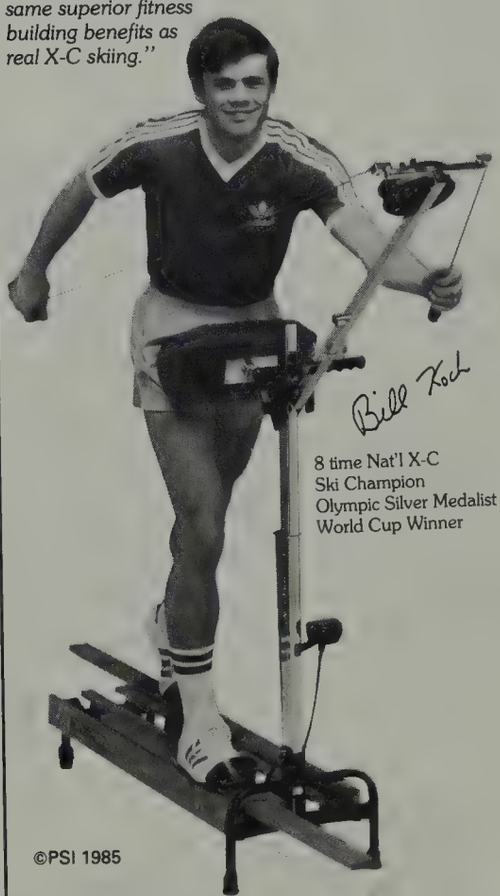

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Planetary Get-together

by Thomas D. Nicholson

This year's gathering of the planets in the morning sky begins to pay off in March, but it will get substantially better in the coming months. For now, however, Mars and Saturn put on a good display, and Jupiter moves into place at the end of the month.

At the beginning of March, Mars and Saturn, with the nearby star Antares, form a large triangle in the southeast and south as they rise in the sky from about midnight until dawn. All of them are about equal in brightness, but Mars and Antares are of a ruddy color. Mars brightens considerably during March and moves rapidly eastward out of Ophiuchus and through Sagittarius, stretching the triangle (with Saturn and Antares). By the end of the month, Mars is the brightest of the three. The planet will continue to increase in brightness in months ahead as it comes closer to the earth.

Jupiter is east of Mars and Saturn, in Aquarius. Although it entered the morning sky in late February, it cannot be seen in the east before sunrise until late March. During the last week, we should be able to see it low in the east at about dawn.

Venus dawdles along as an evening star, setting behind the sun. It is bright enough to see, but because it sets soon after the sun, it will be visible only in a very clear, unobstructed sunset sky. Mercury, considerably dimmer than Venus, shares the evening with Venus until midmonth, when it enters the morning sky.

Events in the calendar below are given in local time unless otherwise indicated.

March 1: A perigee moon (nearest the earth) is up at dawn, setting about 9:00 A.M. It rises again in Libra just about midnight, a day and a half before last quarter.

March 3: The morning moon works its way past Saturn, Antares, and Mars. At dawn it is near the center of the triangle they form but a bit closer to Saturn than the others. Last-quarter moon is at 7:17 A.M., EST.

March 4–5: Sagittarius welcomes the waning crescent moon, which is up in the east by dawn. It will rise later and lower daily relative to the stars of the constellation. Look for the "teapot" in order to recognize the Archer, below the moon on the 4th, and above it on the 5th.

March 6: Mercury is still well placed in the evening, above the western horizon at dusk, but it has dimmed considerably since February. It begins its retrograde motion today and begins to accelerate more rapidly toward the sun.

March 7: This is the last day to see the morning crescent moon before the sun's glare masks it.

March 8: Venus and Mercury, the two planets inside the earth's orbit, are in conjunction with each other. However, both are too close to the sun to be seen.

March 10: New moon, at 9:52 A.M., EST, is in Pisces.

March 12: Our first glimpse of the early crescent moon, still in Pisces, is in the wes after sunset.

March 13: Hamal and Sheratan, the Ram's brightest stars, are above the moon and to its right, but they set early in the evening.

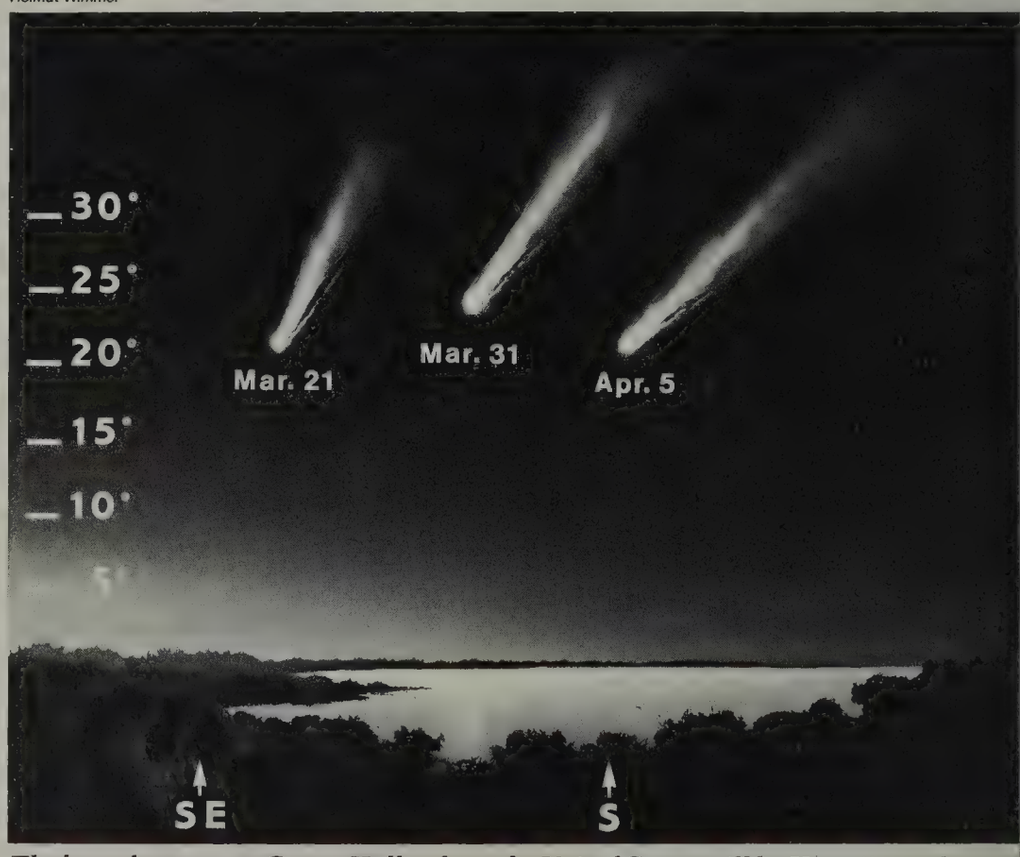
March 15: A widening crescent moon crosses into Taurus, moving below the Pleiades, the cluster of dim stars known as the "Seven Sisters."

March 16: The moon is at apogee (farthest from the earth) and forms a triangle with Aldebaran (to its left) and the Pleiades (to its right). Mercury becomes a morning star (passing between the earth and the sun).

March 17: The days and nights will be approximately of equal length in the Northern Hemisphere.

March 18: The moon is in Taurus when

Helmut Wimmer



The best places to see Comet Halley from the United States will be Hawaii, southern Florida and Texas, and central Florida and the Gulf Coast, in that order. The view above illustrates what observers in southern Florida and Texas can expect to see from mid-March to early April, at about dawn. The comet will be even better located from Hawaii, but it will not be so well positioned along the Gulf Coast. Bear in mind that a bright moon will be in the morning sky from March 24 until April 4.

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it reaches first quarter at 11:39 A.M., EST, but it moves into Gemini before we can see it tonight.

March 19: Saturn is still in the morning sky, rising about midnight. It begins its retrograde motion today, a sure sign that it will soon become an evening star.

March 20: One of the two points of intersection between the plane of the equator and the plane of the earth's orbit is the vernal equinox in southern Pisces. The sun reaches the vernal equinox today at 5:03 P.M., EST, and spring begins in the Northern Hemisphere.

March 22–24: The waxing gibbous moon is up each night at sundown in Leo. It moves past Regulus, the Lion's bright star, during daylight hours on the 23d.

March 25: The full moon at 10:02 P.M., EST, is in Virgo near the autumnal equinox (opposite where the sun is in Pisces near the vernal equinox).

March 26–27: Spica is the bright star near the moon on both nights.

March 28: The moon is in Libra, at perigee for the second time this month.

March 29: Mercury, now a morning star, loops back into direct (easterly) motion again.

March 29–30: Look for the late night moon on both evenings. Antares (below) and Saturn (above) are to its left on the 29th, to its right and closer on the 30th. The gibbous moon glides between them on the 30th.

March 31: No moon tonight. It rises just past midnight in Sagittarius, but it does cover the star Antares (an occultation) at about 8:00 A.M., EST, above the horizon in the northwestern part of North America.

Editor's Note: The Sky Map in the January issue shows the evening constellations and stars for this month and gives the dates and times for use.

Halley's Comeback

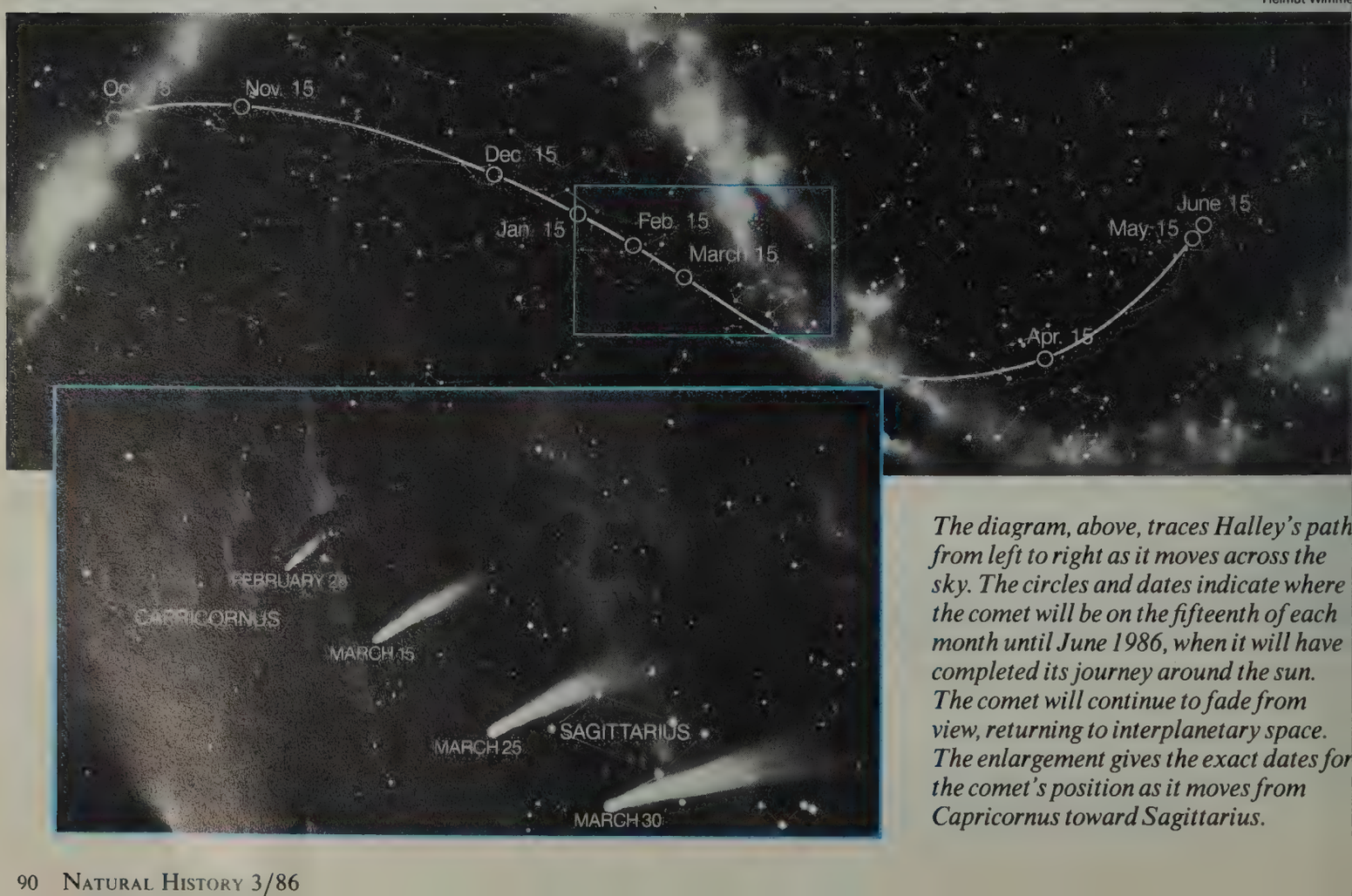
During December and January, Comet Halley proved to be readily visible with binoculars if you knew where to look and had some luck with the weather. If anything, it was somewhat brighter than predicted, although it did not display much of a tail to viewers on earth, in part because of the angle at which we were viewing it. In February, of course, Halley and the earth were on opposite sides of the sun, and we lost any chance of seeing it.

March brings the comet out from behind the sun again and to the sun's right (west), placing it in the morning sky. If the comet develops as it did in 1910, it should have a respectable tail this month. The great, memorable tail our grandparents boasted about (and which we know from pictures of that visit) was seen about a month after the comet's perihelion (closest approach to the sun). That's just abou where it will be in mid-March this yea But there are some differences betwee the two events.

In 1910, the earth came within 14 mil lion miles of Comet Halley on May 18 twenty-eight days after its perihelion. Th 50-million-mile tail it then displayed wa spectacular from the earth's vantag point. It will be twenty-eight days pas perihelion this year on March 11. But eve if it again has a 50-million-mile long tail the earth will be nearly 97 million mile away from it, almost *seven times* the dis tance from which it was seen in May 191 All other things being equal, this Marc the comet should be about *one-fiftieth* a bright as it was on the famous night i 1910 when it was nearest the earth.

There is, however, another difference i our favor. After May 18, 1910, the earth and the comet were separating at almos their maximum combined velocity, sinc they were moving virtually in opposite di rections. But on March 11, 1986, they wil be *approaching* at a combined speed o more than 95,000 miles per hour. In othe words, the distance between them will b shrinking more than 2.2 million miles pe day. Offsetting this fact, of course, is tha Comet Halley is moving away from th sun, reducing both its brightness and th size of its tail. Nevertheless, the combine effect is in our favor; the comet wil brighten through March and into earl

Helmut Wimme



The diagram, above, traces Halley's path from left to right as it moves across the sky. The circles and dates indicate where the comet will be on the fifteenth of each month until June 1986, when it will have completed its journey around the sun. The comet will continue to fade from view, returning to interplanetary space. The enlargement gives the exact dates for the comet's position as it moves from Capricornus toward Sagittarius.

pril, and the tail will probably appear rger as well. Thus, March and early pril viewing should be the best of all uring Halley's 1985-1986 visit to the n's vicinity.

The map of Comet Halley's five-month ash through the inner solar system shows hat it is now moving rapidly south of the rth's equatorial plane. We have seen hat effect this will have on viewing from North America (*Natural History*, Februry 1986). As with any other celestial obct south of the earth's equator (the sun in December, for example), the comet will ot rise very far above the horizon for orthern viewers on March 11, when it is 0° south of the equator. From then on hings go progressively downhill. By the nd of March, the comet is nearly 40° outh of the equator, and it barely comes bove the southern horizon for viewers at he northern midlatitudes.

That is why the March viewing window as lured so many comet seekers southward. Traveling to the equator or to the Southern Hemisphere is best, but even outherly areas of the Northern Hemiphere offer good conditions. For most of he United States, viewing will range from air to impossible. Areas such as New York, Chicago, Denver, and San Francisco could have a shot at it from about March 15 to March 31. The comet will be n the southeast, rising to about 10° above he horizon just before daybreak, with its tail extending upward to the south to an altitude of possibly 20°.

Conditions will be somewhat better along the Gulf Coast of the United States. The morning comet will be 10° or more above the horizon at daybreak or earlier from about March 5 to April 10 and as much as 20° high from March 21 to 31. Viewing improves steadily there to about 30° south latitude, with the comet rising higher in the sky earlier in the night, and remaining in an excellent viewing position right up to dawn.

No matter where you are, moonlight will be a problem from about March 24 until early April. The moon is full on March 25, and the waning moon will brighten the morning sky substantially until it shrinks to a small, thin crescent about April 4. The comet's southerly path takes it in front of the bright regions of the Milky Way in Sagittarius during late March and early April.

At best, the odds are not exactly stacked in our favor. At worst, we are simply behind the eight ball. But the chances of seeing Comet Halley this March and April are still a lot better than they may be on the comet's next time around in A.D. 2062! □

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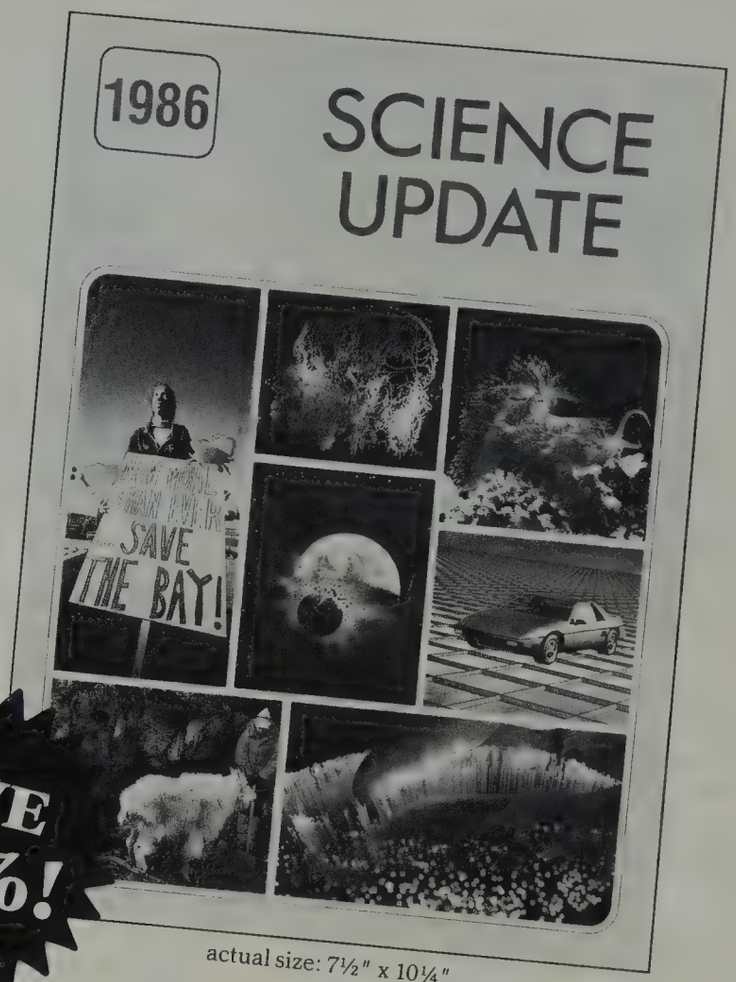

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Finds of a Lost Mission

On an uninhabited island four miles off the eastern seaboard, anthropologist David Hurst Thomas has been excavating the oldest church discovered to date in the United States. The church, Thomas says, was built sometime between 1566 and 1580, before Sir Walter Raleigh brought the first British settlers to Virginia and before the Mayflower landed at Plymouth Rock. More than 100,000 artifacts, ranging from shards of Indian pottery to bronze crucifixes have been uncovered at the site. "In the church alone," Thomas says, "we have found more strictly religious paraphernalia than in all other Spanish missions in the United States put together."

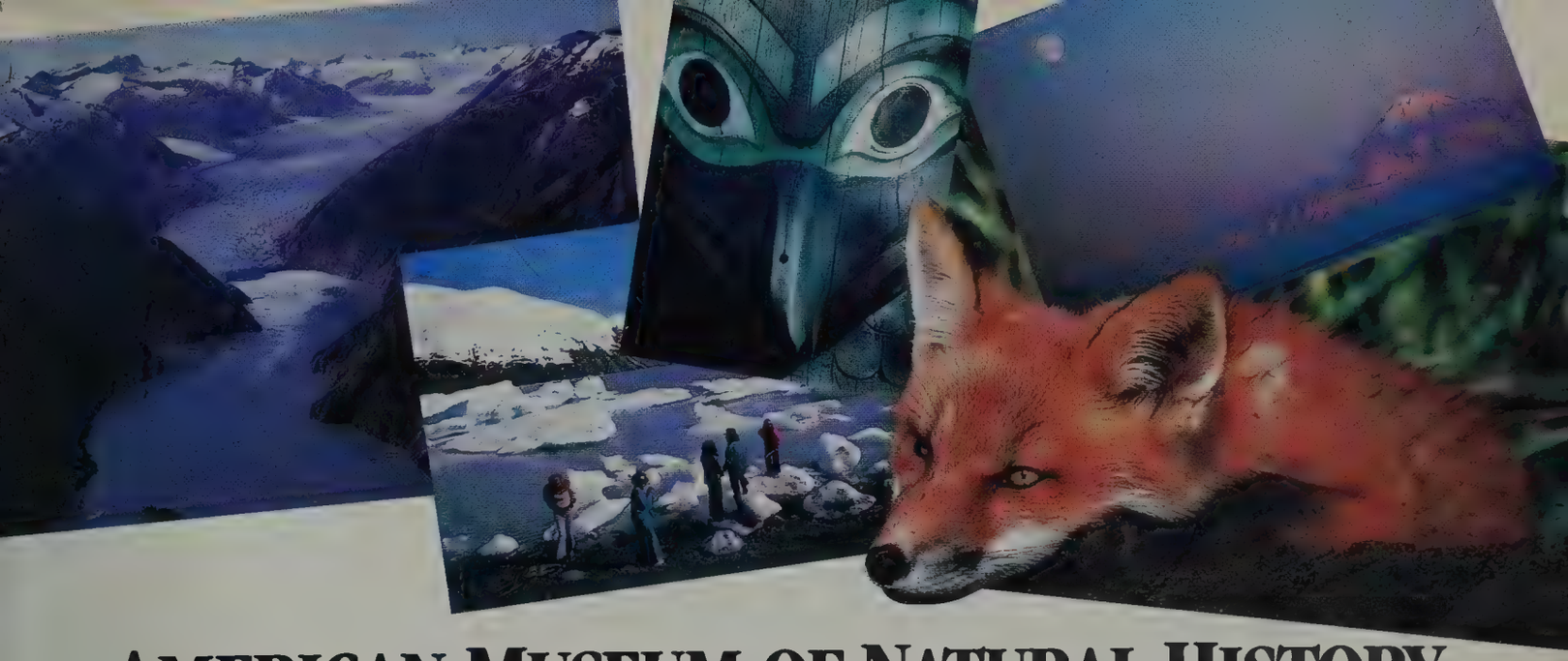
Spanish soldiers and Franciscan priests founded the settlement of Santa Catalina de Guale on the southern tip of what is today Saint Catherines Island, Georgia, a nature preserve owned by the Edward John Noble Foundation. In 1972, the American Museum of Natural History entered into an agreement with the foundation to administer grants for research of the island's natural resources. Two years later, Thomas, curator of anthropology at the Museum, set off to find the mission. The last-known account of the settlement was written in 1687 by a British naval captain who had taken possession of the island. After that, it was "lost" until Thomas, using advanced underground sensing equipment, located the mission's well, church, friary, and kitchen in 1981.

Thomas found the church walls, made of reed and branches cemented with clay, under less than six inches of soil. Normally, these walls would have decomposed within a matter of decades. But sometime before hurricane-tossed soil and the encroaching forest buried the mission, a fire broke out, hardening the clay in the same way that a kiln hardens pottery. Inside the church, the bodies of more than 600 Guale Indians have been found beneath the nave, which in European churches traditionally served as a cemetery. "The Indians buried in the church all received proper Christian burials," Thomas says. "Their feet were pointed toward the altar, and their hands were crossed on their chests." A number of spectacular religious artifacts have been recovered from the graves. Near the site of the church altar, Thomas's crew found a 24-carat gold medallion the size of a man's palm; on its face is an engraving of the Virgin Mary, surrounded by the inscription, in Spanish, "Conceived without original sin." Not far from that grave, an infant's skeleton was found clutching another medallion, struck from gold and silver and depicting Mary grieving over the body of Jesus.

The discovery of grave goods with many of the burials has allowed Thomas to guess at the identity of some of the Indians interred in the church. Those with the most valuable items were all buried nearest the altar. Some, such as the baby, were very young and could not have accomplished much during their lifetimes, indicating they were born into positions of high status. A skeleton of a twelve-year-old was found with an unbroken majolica pot, a Spanish-made ceramic. The pot, Thomas says, may have come all the way from Spain or from at least as far as Mexico City. Around the skeleton's neck was an Indian-made pendant. Cut from a shell and engraved with a rattlesnake motif, this particular symbol has never been found among a historic population. Thomas says that this individual might have been a chief or perhaps an heir to the tribal throne.

AMNH; Dennis O'Brien

A Spanish medallion found at Santa Catalina de Guale



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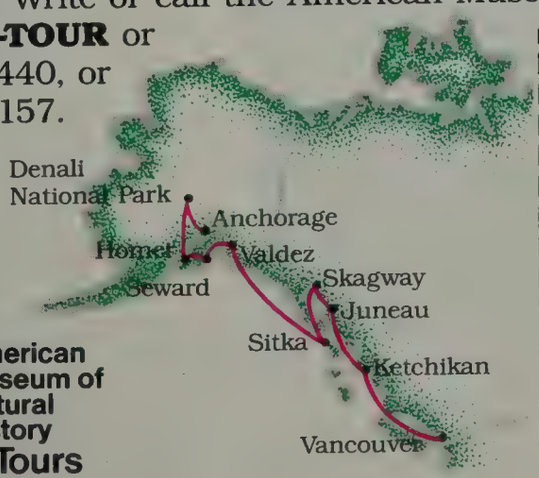

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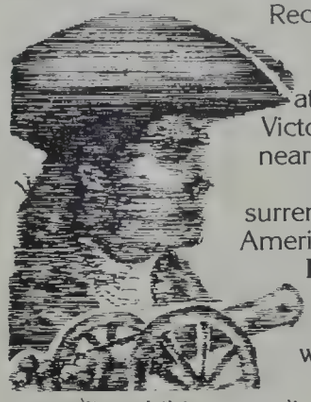

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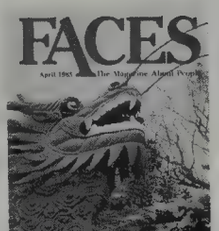

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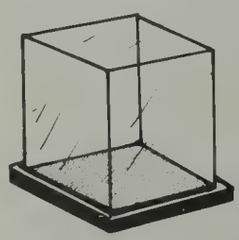

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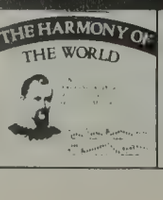

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The Museum keeps a team of researchers on the island almost continuously throughout the year. The scientists live and work in converted slave cabins near the mission and commute to the dig in four-wheel drive vehicles, the only means of transportation on the island. The mission complex itself covers about one and one-half acres; radiating from a central plaza are the church to the west, an Indian village to the north, and the kitchen, well, and friary to the east. Both the church and friary, Thomas says, were rebuilt sometime during the mission's history. Their destruction may correspond to an Indian revolt in 1597, when Guale from the Georgia coast attacked the mission and killed two Franciscan priests. Surrounding the "sacred" part of the mission (the church, well, kitchen, and friary) is a palisade, probably erected after 1670, to protect the complex from British colonists pushing south into territory claimed by Spain. (By 1680, the British would force the Spaniards to abandon the mission.)

As skeletons are excavated, they are brought to the island's archeological laboratory, where Clark Spencer Larsen, a research associate at the Museum and director of the Anthropology Museum at Northern Illinois University, has been conducting paleoautopsies. In less than 100 years, Larsen estimates, the Guale population dropped from 1,000 to fewer than 100. Examination of the teeth and bones of the skeletons buried in the church has shown that widespread malnutrition afflicted these Indians. The Spaniards, Larsen says, forced the Indians to grow food and perform manual labor. By restricting the Indians' movement along the Georgia coast and offshore islands such as Saint Catherines, the Spaniards prevented the Indians from hunting for game and gathering nuts and berries. Subsisting on a diet based on high-sugar, low-protein corn, the Indians, Larsen says, suffered from severe tooth decay and stunted growth.

Infectious diseases and poor sanitary conditions hastened the decline of the Guale. Letters from Spanish governors to the Crown reported that five times between 1569 and 1659 epidemics of measles, smallpox, and influenza, among other diseases, swept through the Indian population. The mission skeletons also show widespread evidence of what Larsen calls "nonspecific" diseases—infections that were caused by generally poor hygiene among the Indians. Already weakened by malnutrition, the Guale had little resistance to sickness: adults died in their early thirties, and rarely did an individual live past the age of thirty-five.

The excavation of the mission site will e completed sometime early this year. ork on the mission will then shift to iiversity and American Museum labora-ries. Researchers from Johns Hopkins nd Harvard universities will continue to nalyze the skeletons, measuring the ones and looking for trace elements that ill tell them more about the Indians' diet. leanwhile at the Museum, the 100,000-plus artifacts will be cleaned, cataloged, and conserved; the volumes of data analyzed. The scientists plan to present their preliminary findings in the Museum's anthropological papers early next year. After that, Thomas says, a scholarly book will be published, and then, perhaps, a popular book on the archeology of Santa Catalina de Guale.

Marshall Schwartzman

At the American Museum

Tales for a March Evening

Toads and skunk cabbages, shopkeepers and neighbors, the mysteries of vacant lots, and other memories of growing up in Brooklyn during the 1940s are the major themes of Gioia Timpanelli's storytelling program. A gifted storyteller, writer, and broadcaster, Timpanelli has told her tales in Ireland, Canada, and throughout the United States, and will do so again on Friday, March 7, at 7:30 P.M. in the Kaufmann Theater. Tickets are $5.00 for members and $8.00 for nonmembers and must be ordered in advance. For additional information call (212) 873-1327.

Chesapeake Bay

The grasses of Chesapeake Bay shelter molting crabs and serve as indicators of water quality. But all over the Chesapeake area, these grasses are dying. Why? On Tuesday, March 11, Michael W. Fincham will present his award-winning film *Chesapeake: The Twilight Estuary,* which explores the ecology of the bay and highlights the scientific detective work that has uncovered a surprising problem: the bay's grasses are being killed by too much life. The film will be shown in the Main Auditorium at 7:30 P.M. It is free and open only to members. Tickets must be ordered in advance. For additional information call (212) 873-1327.

The All-New Dinosaur Revue

In a participatory family program, naturalist-entertainer Mike Weilbacher will explore a wealth of facts and theories about dinosaurs. The *Dinosaur Revue* will include a dinosaur game show, a tyrannosaurus chorus, and an opportunity for children to form a nest of eggs and hatch into dinosaurs. Geared for children ages four through eight, the program will take place in the Kaufmann Theater on March 15 and 16, at 11:00 A.M. and 1:30 P.M. Tickets are $2.50 and are available only to members. For additional information call (212) 873-1327.

Latin America Month

March is Latin America month at the Museum. The richness and diversity of Latin American cultures will be celebrated each weekend in art, song, dance, film, lectures, and workshops. For a complete list of activities call (212) 873-1300, ext. 514 or write for a free flier to Community Programming, Department of Education, American Museum of Natural History, 79th at Central Park West, New York, New York 10024.

At the Hayden Planetarium

Starborn, the Hayden Planetarium's newest Sky Show, explores an extraordinary planet—Earth. Premiering on March 6, this show takes the audience back five billion years to a time when the earth and sun were cosmic clouds. Viewers will then travel through the eons to witness the evolution of our planet from a gaseous to a liquid to a partly solid state. Torrential rains, volcanic activity, crustal movements, and other forces that have shaped the earth are depicted, and historic human beliefs and questions about our planet are explored. For show times and prices call the Planetarium at (212) 873-8828.

For Young People

This year's *Workshops for Young People* include courses for all age groups, on topics such as animals without backbones (for grades 7 through 9), marine animals (for grades 5 and 6), Native American lore (for grades 3 through 5), a special introduction to the Museum for five- and six-year olds, and much more. Fees for the workshops, which begin in April, range from $10.00 to $30.00. For a free brochure call (212) 873-7507.

The Spirit of Africa

On Wednesday, March 26, the Drum and Spirit of Africa Society will present a program of poetry, African folklore, music, and drama that celebrates African culture, focusing on Senegalese dance, song, and drumming. This multi-media performance will take place in the Main Auditorium at 7:30 P.M. Free tickets can be obtained by mailing a self-addressed, stamped envelope to *Spirit of Africa*, Department of Education, American Museum of Natural History, 79th Street at Central Park West, New York, N.Y. 10024. For additional information call (212) 873-1300, ext. 514.

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The Sweet Potato Perplex

Is the yam a sweet potato—or vice versa?

by Raymond Sokolov

Like most of you, I had a yam problem without knowing it. I thought that yams were very much like sweet potatoes, only not as nice. If you had pressed me as to why I held this view, I couldn't have told you. Somehow I had picked up this widespread form of American tuber snobbery.

It came to this. Supermarkets tended to sell yams more frequently than "true" sweet potatoes. But the knowing customer would do his or her damnedest to buy sweets.

Last fall, I decided to test this notion. At a produce market in Ulster County, New York, I purchased some yams and some sweet potatoes. The store labeled the two varieties of very similar long tubers, with similarly tapering ends, clearly, but positioned the sweets as if they were exotic items, like mangosteens or loquats.

Although they looked alike, it was possible to distinguish them at a glance. The yams were a touch larger and had reddish skins; the sweets had brownish skins. Under the skin, the distinctions were even more obvious. The yam was the familar deep orange I had grown up detesting when it was served up under marshmallows as candied sweet potato at Thanksgiving. The "true" sweet potatoes had pale yellow flesh, drier than the yams' and more like that of the conventional potato. As to taste, the more unctuous yam seemed to me more desirable.

So much for sweet potato elitism, I thought. Then I received a copy of *Sweet Potato News* in the mail from Gleason, Tennessee, a k a 'Tatertown. This eight-page flier is published by a local grower named Dudley Sanders, a k a the 'Taterman. His paper is full of facts about sweets, listing varieties (Nancy Hall . . . "an all-time favorite, the 'yellow yam' that granddaddy used to grow many years ago"), giving the news about a ten-pound two-ounce 'tater, explaining modern methods of cultivation under black plastic sheeting, and reminding us that George Washington favored sweets. Sanders also tackles the yam–sweet potato question circumspectly. "The 'Taterman calls them all sweet potatoes," he writes, "because, using all the information he has found, that is what they are."

The 'Taterman goes on to describe a distinction he says the U.S. Department of Agriculture makes between "moist flesh" and "dry flesh" sweet potatoes (a description of the tastes of cooked tubers, not their physical moisture). Then he says: "Yam is a trade name that refers to the moist flesh type of sweet potato. This helps keep people confused about sweet potatoes and yams."

Yes, it certainly does. "Yam" may not actually be a registered trade name, but it is certainly a marketing device, meant to give luster to moist, orange-fleshed sweet potatoes.

Behind this pointless confusion and creative mislabeling lies one greatly clarifying fact. All the yams and sweet potatoes that the 'Taterman is talking about—the moist, the dry, the yellow, the orange, the Georgia jet, and the vineless Vardaman—belong to one species, *Ipomoea batatas*.

The genus *Ipomoea* was named by Linnaeus and means "resembling the convolvulus." And indeed its 500 mainly tropical species are in the Convolvulaceae family. The morning glory is an *Ipomoea*, but the most important congener is *I. batatas*. Originally found in tropical America, it now flourishes throughout the warm parts of the world. In this country, New Jersey is the northern limit of its usual range. Pennsylvania is the major growing state, according to the 'Taterman. The dry-flesh varieties do better in the northern growing areas; the moist, in the south. Sandy soil, low in nitrogen is recommended.

Sweet potatoes are, of course, altogether unrelated to ordinary potatoes and are not propagated, as potatoes are, by simply being cut up in pieces and planted. Instead, whole tubers are allowed to sprout roots and then planted whole. After harvest, they must be cured (partly dehydrated) at about 85 degrees for about ten days; otherwise they will quickly spoil.

Murray Alcosser

Yams (sweet potatoes)

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The foliage of *I. batatas* is familiar to millions of noncommercial growers who have partly suspended a sweet potato in a jar of water by sticking toothpicks into it and then perching the toothpicks on the lip of the jar. Sweet potato flowers, like almost all *Ipomoea* flowers, are funnel or bell shaped, like those of *I. purpurea,* the morning glory. *I. purga* is the source of the purgative drug jalap and is native to Mexican woodlands; *I. tricolor* contains LSD in its seeds.

Even when limited to the edible species *(I. batatas)*, a thorough investigation of the genus *Ipomoea* would range from China to Africa. In Mexico and Hispanic America, a sweet potato purée is a sought-after dessert (see recipe). In her encyclopedic new book, *Classic Indian Vegetarian and Grain Cooking* (Morrow), Julie Sahni writes about a *poori,* a puffed bread whose dough contains puréed sweet potato. Brazilian cuisine includes sweet potato soup, candy, puffs, and dinner rolls.

I suspect that the fairly long list of sweet potato recipes now available in American cookbooks is only a small sampling of all the dishes developed for this tuber around the world over several centuries. For instance, I have not found any Chinese recipe, although it is certain that Chinese people have long known sweet potatoes and cooked them frequently.

Hispanic America, the probable home of *I. batatas,* seems to be the richest source of sweet potato dishes, but it is not easy to get a full sense of what has been or is being done by Caribbean and South American cooks because, along with black Africa, Latin America is a culinary dark continent: barely any reliable cookbooks for these regions have been published here. But one gets an overall idea of what exists from Elizabeth Lambert Ortiz's standard *The Complete Book of Caribbean Cookery* (M. Evans).

Her index refers to two sweet potato breads, one with coconut mixed in, as well as cakes from Haiti, Martinique, and Cuba; sweet potato chips; a sweet potato crust for chicken pie; a dessert paste; a pone; and a tart. The most tantalizing fact about this repertory is that the sweet potato most prized for many of these recipes—the variety most admired in the region where sweet potatoes are most used—is neither our yam nor our "true" sweet potato.

The *boniato* (or *batata* or *batata dulce*) is an almost spherical, small tuber with a single point. Its skin is brown or pink; its flesh, white. And its flavor, while less sweet and sultry than our local varieties, is far more aromatic. Islanders prefer it. So will you.

Boniatos are not hard to find. Now that I know what to look for, I see them everywhere—in the vegetable bins of little Hispanic bodegas and even in New York supermarkets. Usually, they are labeled *batatas,* if they are labeled at all. The assumption of the grocers selling them seems to be that people who are likely to buy them will already know what they are. You and I, after all, don't need a sign to tell us that conical orange vegetables with lacy green tops are carrots.

So the *boniato* lurks within the hermetic world of *productos tropicales,* anonymously for sale in every big city in this country but almost completely ignored by Anglo cooks, even those with a passion for the exotic. And in those same bins, beside the boniatos, lie various hairy, wrinkled root vegetables known by a host of imprecise or confusingly multiple dialectal names. Some of them are taros (*malanga, tannia*); others are cassava (yucca). Still another is the true yam (*ñame, mapuey*).

They look nothing at all like sweet potatoes nor are they related. The roughly 600 species of true yams spread throughout the world's warm countries are all members of the genus *Dioscorea,* which is named after the ancient naturalist Dioscorides. The Central American *D. composita* is a natural source of cortisone. *D. elephantipes,* or Hottentot bread, grows to a humongous 700 pounds in the deserts of South Africa. *D. alata,* the winged or water yam, is distributed worldwide and may extend six feet in length and weigh 150 pounds. As far as I can tell, the much smaller, cylindrical, brown-skinned, white-fleshed yam normally sold in my Manhattan neighborhood is either *D. alata* of modest size (2 feet long, 4 to 5 pounds) or *D. trifida,* 6 to 8 inches long and very similar in taste quality. The vernacular name yam derives from a West African word that came into Spanish as *ñame,* French as *igname,* and Portuguese as *inhame.* One imagines that slaves brought the word to these shores and applied it to sweet potatoes because they were also tubers.

Apart from its size and the confusion that surrounds it in American life, the yam is not a vegetable likely to interest people who already have access to the potato and who can easily latch on to the *boniato.* The true yam has a neutral, starchy flavor.

The yam seems to have originated in Asia and was eaten in China from earliest times. West Africans depend on it, although its protein content is small. Perhaps the best thing that can be said about it is that it really is a yam.

Raymond Sokolov is a writer whose special interests are the history and preparation of food.

Boniatillo

(Cuban dessert made from the *boniato* sweet potato, slightly adapted from *The Complete Book of Caribbean Cooking,* by Elisabeth Lambert Ortiz, M. Evans)

- 1 pound *boniatos* (pink- or white-skinned, white-fleshed sweet potatoes available in Hispanic markets), peeled and sliced
- 1½ cups sugar
- Peel of 1 lime
- 2-inch stick cinnamon
- 3 egg yolks, lightly beaten
- ¼ cup sherry
- 1 cup heavy cream

1. Boil the *boniatos* in water to cover, until tender, about 25 minutes. Drain and push through a potato ricer. Do not use a blender or processor, which will turn the potatoes to glue. You should have about 2 cups.
2. While the potatoes cook, combine sugar, use ½ cup water, lime peel, and cinnamon in a saucepan. Boil until the resultant syrup reaches the soft ball stage (250 degrees on a candy thermometer). Discard the peel and cinnamon.
3. Stir the syrup into the *boniato* purée. Cook in a heavy saucepan over low heat, stirring constantly until the mixture makes a thick paste.
4. Off heat, stir in the egg yolks and mix well. Return to heat and cook, stirring for 2 or 3 minutes. Remove from heat and stir in sherry. Cool. Serve with cream on the side.

Yield: About 3 cups

Yam Purée

- 2 pounds medium-size yams (*ñame* or *mapuey* in Hispanic markets)
- 1½ tablespoons lemon juice
- Salt
- ⅔ cup milk
- ¼ pound lard or butter
- Cayenne pepper

1. Peel and slice the yams. Boil in water to cover with lemon juice and salt until tender, about 30 minutes.
2. Drain yam and push through a potato ricer (Do not use a blender or processor, which will make the yam gluey). Beat in milk and lard or butter. Season to taste with salt and cayenne. Serve as a side dish, much as you might serve mashed potatoes.

Yield: Six servings

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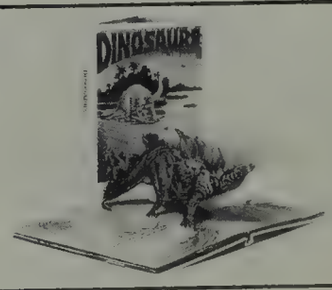

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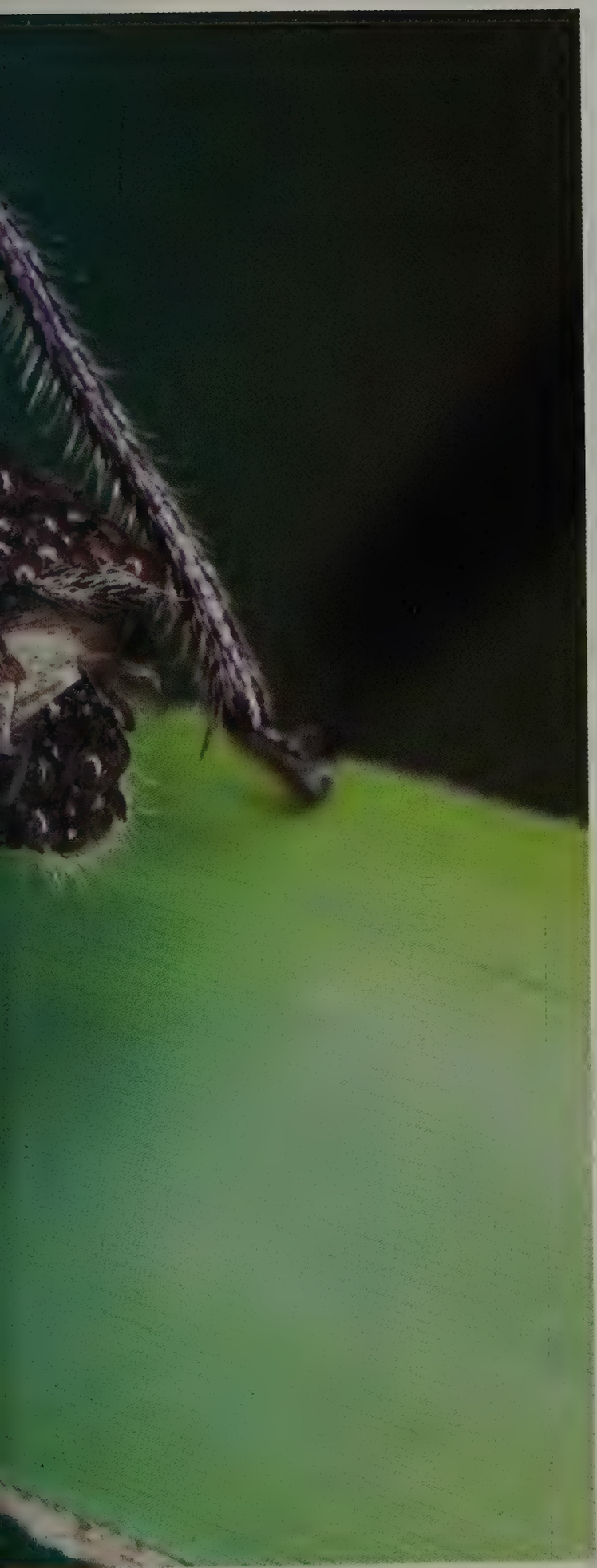

Buggy Ride

It's hard not to sympathize with this long-horned beetle, staggering along a palmetto leaf in the Florida heat, with a load of mites on its back and a hitchhiking pseudoscorpion clamped to a leg. Just as a mammal often carries a cargo of insects, so insects frequently act as food, lodging, and transportation for other, smaller organisms. Distinguishable only by specialists, dozens of types of mites exist, each with its own mode of parasitism. Many simply eat bits of organic material that have accumulated on their host's back. Some, like the passengers at left, always seem to position themselves symmetrically along their host's center of gravity, an arrangement that may have evolved so the host can move unimpeded.

If the mites regard the long-horned beetle as a bed and breakfast, the pseudoscorpion treats it as a taxi. Long-horned beetles bore into wood when they are in the larval stage, emerging later as adults. Sometimes they take so long to transform that the tree they burrowed into has itself been transformed in the meantime, and horrified householders spot the beetles tunneling out of a new dining room table. If the tree is still standing, the beetle must crawl through layers of bark—home territory to pseudoscorpions. On its first sojourn in the outside world, a beetle may find one of these tiny bark dwellers pincer locked to a limb. Pseudoscorpions are sedentary arachnids that use long-horned beetles to disperse from their birthplace. They hang on until the beetle passes a likely spot for a new pseudoscorpion settlement, at which point, they let go and get on with their primary business: eating and making little pseudoscorpions.

Or, as Jonathan Swift put it:

> So, naturalists observe, a flea
> Hath smaller fleas that on him prey;
> And these have smaller still to bite 'em;
> And so proceed *ad infinitum.*

— Charles C. Mann

Photograph by Tom Eisner

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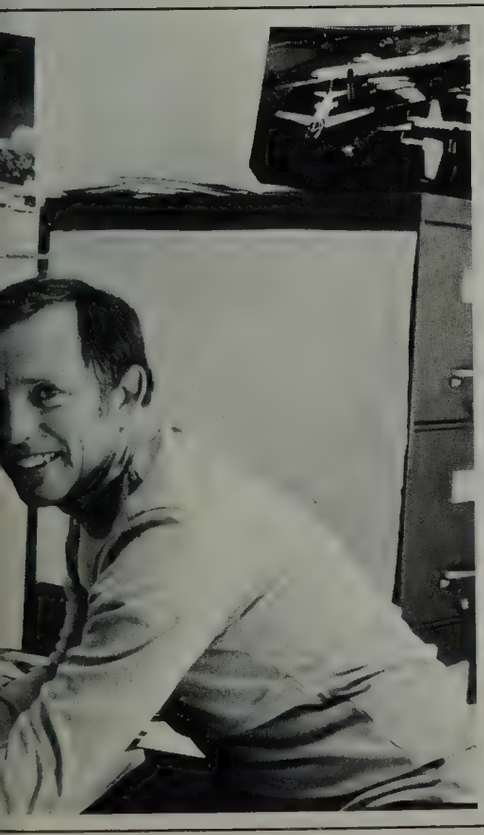
Authors

While studying thunderstorms in Illinois in 1978, meteorologist **James W. Wilson** (page 48) discovered the equipment he was using could detect "very small-scale wind shear events." Since wind shear had been implicated in some plane crashes, he found "it natural to investigate how [that equipment] could be used to improve aircraft safety." Wilson is a scientist at the National Center for Atmospheric Research in Boulder, Colorado. Most of his work involves the investigation of thunderstorms and wind shear all over the United States. He hopes to learn "why some thunderstorms and showers produce strong wind shears, while others do not." For those who want to know more about wind shear, he recommends *The Downburst,* by T. Theodore Fujita (Chicago: University of Chicago Press, 1985) and "The Microburst Hazard to Aviation," in *Weatherwise,* June 1984, published by HELDREF Publications, Washington, D.C.

Scott Robinson (page 38) set out for Amazonian Peru in 1979 to study the foraging behavior of caciques, but he hit on a more exciting focus for his work. "From my first predator attack, I was hooked," he says. He has spent parts of six years observing caciques defend themselves against predators attracted to their hanging nests. A scientist with the Illinois Natural History Survey, Robinson received his doctorate in population biology from Princeton University. Books that deal with North American relatives of caciques include Gordon Orian and Tony Angell's *Blackbirds of the Americas* (Seattle: University of Washington Press, 1984) and Robert W. Nero's *Redwings* (Washington, D.C.: Smithsonian Institution Press, 1984). Robinson has been a fanatical birder and an avid bird lister since he was twelve years old. He once held the record for the number of North American species seen in one year, 657, and has used his tropical expertise to capture the world Big Day record: 331 species sighted in twenty-four hours.



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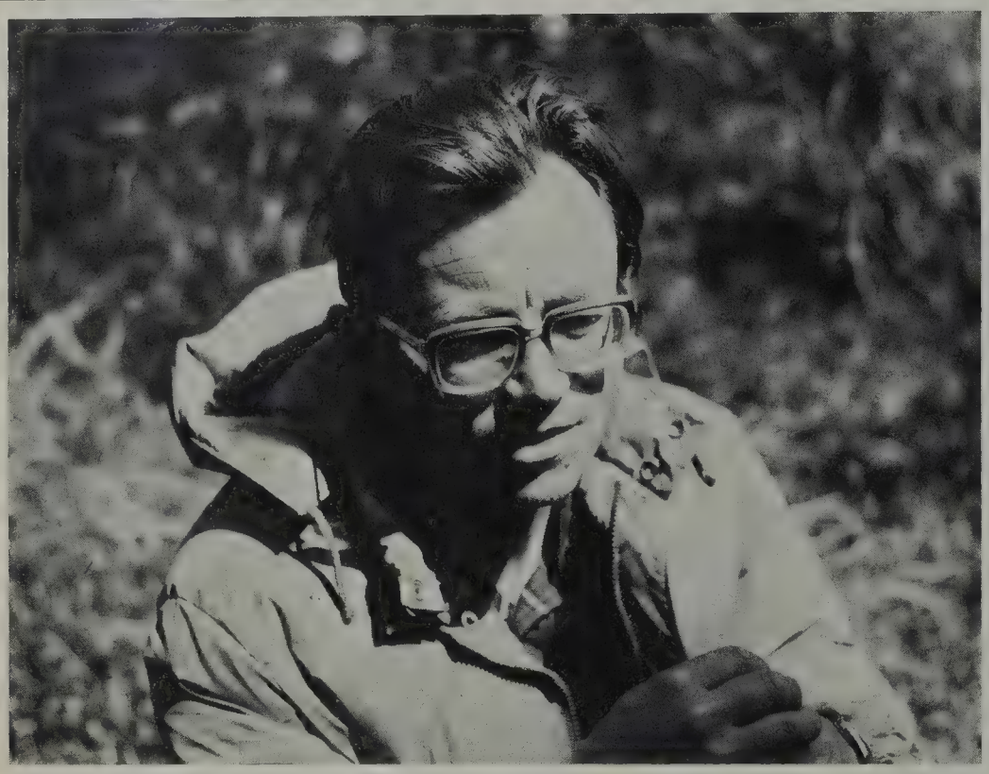
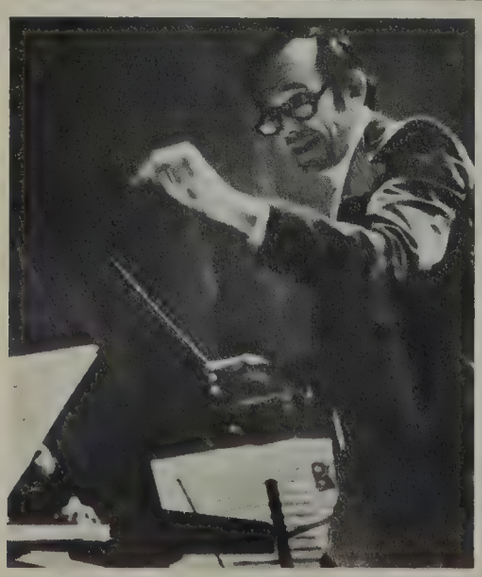


"I became interested in the Irish elk while writing a book on deer evolution," says **Valerius Geist** (page 54). "How antlers evolve is an old, very contentious subject on which I first published material two decades ago." Geist, a professor of environmental science at the University of Calgary in Alberta, Canada, conducts research on the ethology, ecology, and evaluation of large mammals, with special emphasis on ungulates. Most of Geist's fieldwork has been conducted in the Canadian Rockies, but he has also worked in Texas, India, and Europe. Geist is an outdoorsman with a passion—a hunter, a fisherman, and a gardener. He is also a bookworm (great for cold winter nights in a cabin) and suggests readers might profit from R.J. Goss's *Deer Antlers*, published in 1983 by Academic Press, and Stephen Jay Gould's article "The Misnamed, Mistreated, and Misunderstood Irish Elk" (*Natural History*, March 1973).



"I always walk around with a camera," says **Tom Eisner** (page 100), who photographed this month's "Natural Moment." An entomologist and ethologist at Cornell University, Eisner spotted the bug-heavy beetle at the Archbold Station, a biological research center near Lake Placid, Florida. Surprised to see the long-horned beetle during daylight hours, he seized the opportunity—and the beetle—which he then photographed for more than an hour. All the while, its load of parasites hung on, undisturbed by the attention. In his spare time, Eisner conducts the Bi-weekly Rehearsal Association of Honorary Musical Scientists.

Biologist **Gary N. Ross** (page 66) first visited the Zapotec Indian weavers in Mexico's state of Oaxaca while he was in the region surveying butterflies. The Zapotecs' use of an insect dye and of butterfly motifs were among the aspects of their traditional art that turned Ross into an avid researcher and collector of their textiles. In addition to receiving guidance from master weaver Isaac Vasquez, Ross has sought out information from published sources, including *Indian Clothing Before Cortés: Mesoamerican Costumes from the Codices*, by Patricia R. Anawalt (Norman: University of Oklahoma Press, 1981) and *Mexican Indian Costumes* by Donald Cordry and Dorothy Cordry (Austin: University of Texas Press, 1968). A professor of biology at Southern University in Baton Rouge, Louisiana, Ross recently cosponsored an art exhibit with the Arts and Humanities Council of Greater Baton Rouge. Isaac Vasquez, whose textiles were featured in the exhibit, traveled to the United States for the opening. Wearing another hat, Ross has contracted with a Florida travel agency to conduct regular folk-art tours of Oaxaca. Meanwhile, he continues his field studies of the life histories of butterfiies, expanding on research that he described for *Natural History* readers in an earlier article ("The Case of the Vanishing Caterpillar," November 1985).

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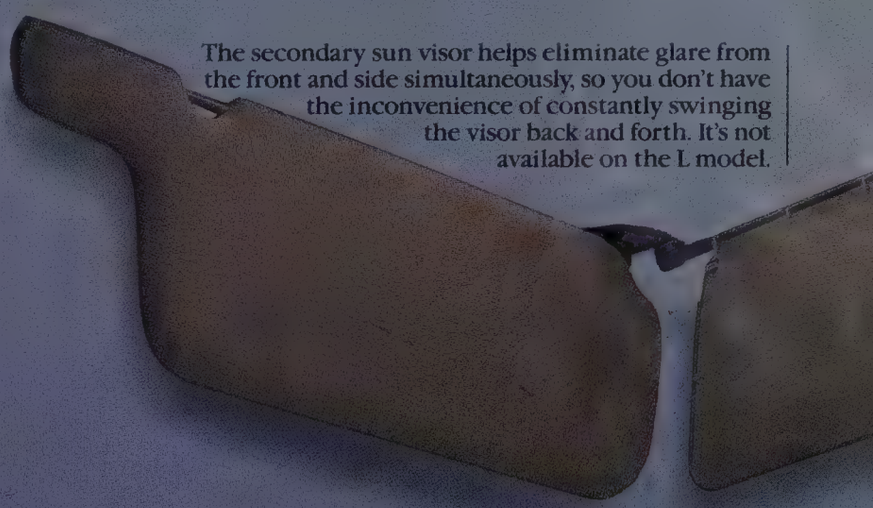

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Males are more likely to have hypertension under 50 years of age and women after 60, but it occurs in both sexes at all ages.

Does it run in families?
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Is race a factor?
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Hypertension is usually associated with being very overweight. (Your doctor would know if you are.) And it's aggravated by high salt intake.

What can be done about high blood pressure?
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Vol. 95, No. 4, April 1986
American Museum of Natural History, New York, N.Y.
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4 Letters

10 Canyon Echoes of the Condor *Steven D. Emslie*
The giant bird's journey toward extinction began 10,000 years ago.

16 This View of Life *Stephen Jay Gould*
Soapy Sam's Logic

28 Reviews *George M. Woodwell*
Staying Alive

32 Wild Horses of the Granite Range *Carol Cunningham and Joel Berger*
Home, home on the range, where the stallion plays for keeps.

41 The Children's Fate *Lester R. Brown, William U. Chandler, Christopher Flavin, Jodi L. Jacobson, Cynthia Pollock, Sandra Postel, Edward C. Wolf*
The special State of the Earth 1986 *supplement looks at the world we are bequeathing to our children. What sort of ecological debts will they inherit? Can we afford both guns today and better lives tomorrow? The prospects are often dismal, but some bright points of hope exist. Illustrated with a portfolio of children's art.*

70 Picnic *à la dauphine* *Photographs by Peter Cram*
Bottlenosed dolphins, which have bigger brains than humans, can teach us a few tricks about fishing.

74 Conjugal Chemistry *John Alcock*
Many species, including humans, seek mates of the same size. Why?

82 Celestial Events *Thomas D. Nicholson*
April Is Not the Cruelest Month

93 The Living Museum *Photographs by Robert Noonan*
New Life from Neblina

98 This Land *Robert H. Mohlenbrock*
Big Thicket, Texas

102 A Matter of Taste *Raymond Sokolov*
The Good Seed

106 The Natural Moment *Photograph by D. Wilder*
In Cold Blood

108 Authors

Cover: *Two young wild horses engage in mock combat in northern Nevada. Story on page 32. Photograph by Joel Berger.*

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Who Are the Kayapó?

Why is the Museum memorializing the Kayapó Indians as warriors ("The Living Museum," January 1986)?

My understanding of the Kayapó is that they are cultivators in northeastern Brazil who grow manioc, maize, and sweet potatoes. Hunting and fishing supplement the garden produce. Members of each village belong to one of two moieties. Each group is politically competitive and lines up against the other for dances, rituals, and games. Their environment is quickly being destroyed. It is conceivable that they will become extinct.

What injustice have we done? First, Western civilization wipes out indigenous peoples, then represents them as savage killers instead of peaceful cultivators. Does this somehow justify our culture's savage behavior?

KATHRYN S. MOLLER
Laytonville, California

The portrayal of a Kayapó warrior in the Amazonian section of our forthcoming exhibit hall, Native Peoples of South America, is fully justified by the facts. Until the early 1960s, the Kayapó were redoubtable warriors. Indeed, Belgian ethnologist Gustav Verswijver has just written a 463-page dissertation on Kayapó warfare.

Of course, the Kayapó did more than fight, and our depiction of them in the exhibit hall will not be restricted to their warfare. We intend, for example, to show a spectacular feather headdress worn by the Kayapó during their tortoise ceremonies, as well as their very precise, fine-line body painting, which is probably the most delicate and controlled in all of Amazonia.

But a more basic issue is involved here. Should a natural history museum suppress certain historical facts in order not to offend the sensibilities of a few? I think not. A natural history museum cannot be in the business of sugarcoating history. Our aim in the exhibit hall is to portray Amazonian Indian culture as it really was, before it was denatured or destroyed by European contact, not in some diluted and romanticized form. If we don't present this rich but vanishing culture to the world, who will?

Of course, none of this means that we condone the crimes that have been perpetrated against Amazonian Indians. If the issue is to be argued on moral grounds, the best way a museum can serve the cause of living Indians is by depicting their traditional culture as faithfully as possible. The public will then have a chance to learn just what it is that is being destroyed. And through agencies like Cultural Survival and Survival International, they can take whatever action they deem fit to try to prevent this destruction.

ROBERT L. CARNEIRO
Curator of South American Ethnology
American Museum of Natural History

Dennis Werner

A contemporary Kayapó Indian

With Malice Toward Spain?

I was disappointed in John Alden's review of *In the Wake of Columbus* and *The Spanish Sea* (January 1986). Alden, I feel, betrays a pervasive anti-Hispanic bias, the effect of the so-called black legend of Spain, discussed by William S. Maltby in *The Black Legend in England: The Development of Anti-Spanish Senti-*

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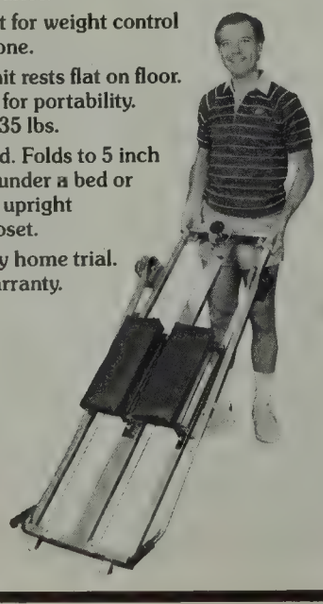

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ment, 1558-1660 (Duke University Press, 1971). For centuries, Professor Maltby says, anti-Hispanism—born out of centuries-old antagonisms—has dominated historical writing in England and elsewhere and has resulted in a highly biased and unfair portrayal of Spain's contributions to the discovery, exploration, and development of the Western Hemisphere.

Alden states that Francisco Fernández de Córdoba was commissioned for a voyage of discovery to the West because he was "very able at kidnapping and killing Indians." Here the actions and the policies of the Spaniards are distorted with malice in an offhand quote. Actually, in 1517 Córdoba was commissioned by Diego de Velázquez, then governor of Cuba, to travel west with three ships and discover new lands. Velázquez instructed Córdoba to go first to the islands of Guanajos to take native prisoners and bring them to Cuba to help pay the expenses of the expedition. Bernal Diaz del Castillo, a member of the expedition, relates: "When we, the soldiers, learned what Diego Velázquez was requesting, we said that it was not just, and that neither God nor our King would order us to make slaves of free Indians." Velázquez rescinded the order and the expedition sailed west, discovering Yucatan. In the town of Champotón, the Spaniards went ashore to replenish their water supply and were ambushed by seemingly friendly natives. Francisco Fernández de Córdoba lost fifty-seven men and was himself badly wounded, dying from his wounds ten days after returning to Cuba.

There were, it is true, cases of native kidnappings against the policy of the King and the *Consejo de Indias*. Spain's record of cruelty is unenviable, but it has to be judged in the context of the times (400 to 500 years ago) and the discovery of the unknown. The natives also had friends and protectors—Montesinos, Bartolomé de Las Casas, Vasco de Quiroga, and others—who had access to the King. Unlike the Puritans in New England, Spain never favored a policy of deliberate extermination of the natives.

Alden suggests that the Spaniards' failure to colonize the gulf coast occurred "because their efforts were parasitical." Explorers, by necessity, had to rely on indigenous food supplies, which the extremely primitive tribes of the gulf coast did not have, and Spanish priorities were directed to more developed areas. Nevertheless, Greater Florida up to New Orleans, and the territories west of the Mississippi up to Illinois, had been developed by the Spaniards and were under their control until the middle of the eighteenth

entury, and on and off during that century's final four decades. Alden's casual haracterization of Spanish colonization s a failure sweeps away two centuries of paniards' work and effort in the region.

FERNANDO S. LEON
Ann Arbor, Michigan

ohn Alden responds:

I hardly feel that it denotes an anti-Hispanic bias to characterize the Spanish ffort to colonize Greater Florida as a ailure: for the period Mr. Weddle's book xamines, 1508 to 1685, it unquestionably vas. Nor do I find Mr. Leon's apologia for Velázquez and Córdoba very convincing. One need only recall how quickly the Caibbean Indians were wiped out or review he results of the notorious *encomienda* ystem in Mexico to reject his claim that I ave maliciously distorted the actions and olicies of the Spaniards in the New World. Extermination may not have been fficial Crown policy, but that didn't nake much difference to the native peoles of Mesoamerica.

Interestingly enough, Mr. Leon's last aragraph makes the same mistake that I elieve doomed Spanish efforts to colonize the gulf coast—failure to differentiate exploration from colonization. A small arty of explorers may be able to rely on ndigenous food supplies, but a colony annot. Had the Spaniards recognized his distinction, the Gulf of Mexico might till be a Spanish sea.

Brazilian Princess

I was fascinated by "The Princess of Brazil" in the February issue of *Natural History,* but was astounded to learn that only a 9.5-pound stone was cut from the original 75-pound crystal. Does this actually mean that 87.3 percent of the crystal was wasted or were smaller stones salvaged from it?

RICHARD S. MILLER
New Haven, Connecticut

The editors reply:

According to Josh Hall, vice-president of Pala International, the firm that cut the Brazilian Princess, most gems represent only 20 to 40 percent of the original crystal. Only the purest part of the crystal—the area freest from bubbles, cracks, or other flaws—is used. The remainder is sawed or ground off and usually discarded as waste.

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April 30, 1986

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Canyon Echoes of the Condor

The giant scavenger, now nearly extinct, once occupied much of western North America

by Steven D. Emslie

For thousands of years, the dry, deep caves that riddle the limestone cliffs of the Grand Canyon have sheltered bones and more fragile organic material and preserved them to a degree seen in few other areas of North America. Among the fossils are the remains of now extinct animals that once inhabited the canyon. In addition to bone, delicate matter such as hair, feathers, and even plant remains have been excavated.

My interest in fossil birds first drew my attention to the caves. Not only were there hundreds of caverns in the Redwall limestone, a 450- to 700-foot-thick formation extending almost the total length of the canyon, but most of the caves appeared to be large and deep, promising that fossils would be found within. High on vertical cliffs, the caves are inaccessible to most animals except birds, an ideal place to search for remains of fossil birds.

I was especially interested in finding remains of *Gymnogyps californianus*. This bird once ranged widely across western North America and Florida and its bones have been found in the Grand Canyon, but its common name, California condor, reflects its present limited range. Fewer than thirty of these large vultures now remain, most of them in the San Diego and Los Angeles zoos. Only a captive breeding program stands between the condors and extinction. Condors prefer to nest in remote caves close to water, and the canyon offers superb conditions. Because the Grand Canyon has been suggested as a relocation site for living California condors, determining the timing and the conditions of the condors' extinction in the canyon and other parts of their North American range was important. I believed some of this information might be found within the caves.

I gathered a crew and, with the permission of the National Park Service, undertook an exploration of twenty caves, some of them probably never before entered by humans. We completed preliminary investigations over a three-week period in April 1983. The team consisted of photographers, paleontologists, archeologists, and the skilled boatmen who moved us all safely down the river.

But without the expertise of two rock climbers, Larry Coats and Dave Dawson, my project would never have gotten under way. We climbed vertical cliffs from below, rappelled from above, or traversed ledges to the cave entrances. We often spent painstaking hours climbing to what appeared to be an excellent cave, only to find it shallow and empty. At other times we maneuvered our way into deep caves that should have contained fossils but had none. In time, our efforts paid off. Many of the caves did contain fossils, some of canyon animals now extinct. Of particular interest was an extinct mountain goat, a

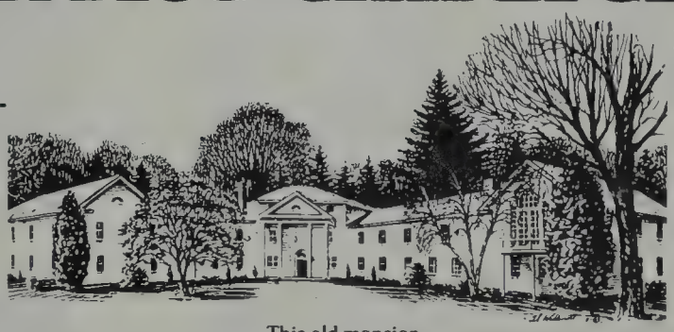
Steven D. Emslie

Caves line the Redwall limestone of the Grand Canyon.

We're looking for people to write children's books

By Alvin Tresselt,
Dean of Faculty

"Writing for children is the perfect way to take up writing," says the author of 53 children's books. "Your ideas come right out of your own experience. And while it's still a challenge, it's the straightest possible line between you and publication—if you're qualified to seek the success this rewarding field offers."



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But after 30 years of editing, publishing, and teaching—and 53 books of my own—I can tell you this: You'll go a long way before you discover anything as rewarding as writing for young readers.

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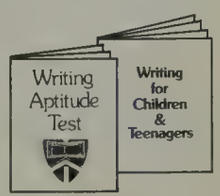

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Alvin Tresselt was Vice President and Executive Editor of Parents' Magazine Press, the first editor of *Humpty Dumpty's Magazine for Children*, and a board member of the Author's Guild. His 53 books for young readers have sold over two million copies.

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cliff-adapted artiodactyl (even-toed animal) that used these caves about 11,000 years ago.

We also found, as I had hoped, abundant bird remains, including bones of falcons, ducks, geese, quail, a raven, and even a woodpecker. Most exciting were the condor bones we discovered in seven different caves. At one time, these birds must have been common in the canyon. At a site we named Sandblast Cave, for our exposed camp on a sand dune nearby, we found bones of at least three condors scattered on the cave floor, prompting me to wonder how many others would turn up with systematic excavation.

The following year I returned to the canyon to excavate this cave and others so that the remains of these birds could be studied. Condor bones found on a cave's floor should represent the most recent occurrence of the species in the canyon. By obtaining radiocarbon dates on these bones, I could determine when the condor became extinct in the area. I spent thirty-five days in the canyon, concentrating on four of the most productive caves.

Sandblast Cave, where I had found the bones of three condors, is a small cavern with three entrances that pierce a corner of limestone cliff overlooking the Colorado River. Each entrance has a short passage, and the three converge in the center of the cave. The front entrance is above the river, while the others face small

Steven D. Emslie

A 12,000-year-old condor skull

drainages on either side. On the floor just inside the front entrance were thousands of unfossilized bones of rodents, birds, reptiles, amphibians, and fish. This area must have served as a roost for various birds of prey, including owls and falcons. The age of the bones, the remains of the prey, is unknown, but is probably not more than several hundred years.

We spent most of our time in the side passage that housed the exposed condor bones. We worked here for ten days, excavating a large pack rat, or wood rat, mid-

CONDOR UPDATE

As of mid-February 1986, only five California condors, four of them male, were known to survive in the wild. This represents a drastic drop from the fifteen wild birds, including five breeding pairs, counted in 1984.

The wild condors roost and nest within Los Padres National Forest, about sixty miles north of Los Angeles, but they range widely and scavenge mainly on private lands in the foothills around the San Joaquin Valley. Lead poisoning is a major threat to the remaining condors. The birds ingest the lead when they feed on carcasses of animals shot by hunters. A fragment of lead can kill an adult condor. On January 18, 1986, one of the last two wild females died of lead poisoning, after she had been trapped and transported to the San Diego Animal Park for treatment.

Condors mature slowly and do not breed until they are six to eight years old. They generally lay only one egg every other year. Four of the wild birds are fully grown. The other, a six-year-old, is close to maturity. Twenty-one condors are now in captivity, eleven in Los Angeles, ten in San Diego. Of these captive condors, only three are adults; two are subadults and the remainder are immature. No condor has yet reproduced in captivity. All of the condor eggs hatched in Los Angeles and San Diego have been taken from the wild. When an egg is removed from a nest in the wild, the female usually lays another. In this way, field biologists who gather eggs hope to accelerate the natural rate of reproduction. The most recent hatching of a condor egg taken from the wild occurred in July 1985 in San Diego.

The U.S. Fish and Wildlife Service has abandoned plans to release three immature condors into the wild in April 1986. Officials fear that the birds are too tame to be safely released. There are currently no further plans to release captive birds in 1986.

Two encouraging events have been reported: an observer from the Condor Research Center in Ventura, California, recently sighted two condors about eighty miles north of the territory of the five known in the wild, in an area used by condors in past years, raising hopes that at least one of these is a previously uncounted wild bird. Scientists also report that the last-known wild female is attempting to lead the wild six-year-old to former nesting sites, possibly to mate.

—*J.R.*

den that nearly filled the passage; each day the findings became progressively more interesting. Pack rats are notorious collectors and will drag all kinds of objects—sticks, plants, bones, and feathers—into their nests. This material is gradually deposited into a midden.

The midden contained the bones of at least five condors. I believe this cave was used by the condors for nesting, because the bones were complete, often found still attached to each other at the joints, and associated with abundant feather and eggshell fragments. Most bones were those of fledgling birds; large-mammal bone fragments in the deposit may be the remnants of the condors' dinners. Although vultures such as condors cannot carry objects with their feet, they often transport food to their nest in their beaks. Condors can also swallow bones while feeding on a carcass and later regurgitate them at the nest. Similar kinds of bones are found at nests of the California condor today and include those of horses, cows, and deer. But the bones we found were from animals long extinct: camels, mountain goats, and bison of the Pleistocene epoch, which ended more than 10,000 years ago. Their carcasses probably formed the bulk of the condor's diet.

Before leaving Sandblast Cave we located a layer of washed sand and driftwood below the midden. The cave is now situated 125 feet above the Colorado River, and the driftwood must have accumulated when the canyon was flooded or before the river eroded to its present level. In the future, similar finds may help determine erosion rates and the canyon's age.

Stevens Cave, named after its discoverer, naturalist and canyon expert Larry Stevens, was the largest cave we explored.

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Emilee Mead

A rock climber nears a cave entrance.

Deep inside on the cave floor lay a complete condor skull. The specimen is beautifully preserved, has an intact beak, and even retains some dried skin, perfect material for obtaining a radiocarbon date. At no other fossil site in North America has such a complete bird skull been found.

I submitted sixteen samples of bone and tissue, mostly the remains of condors, to the University of Arizona Radiocarbon Laboratory. In the past, samples of fifty to one hundred grams of organic matter were often needed to obtain accurate dates. This requirement usually meant that bones of smaller animals, such as birds, could not be dated directly by this method. With the recent development of the tandem accelerator, however, scientists can register accurate radiocarbon dates with as little as one to three grams of material. The remains of many fossil birds can now be precisely dated for the first time.

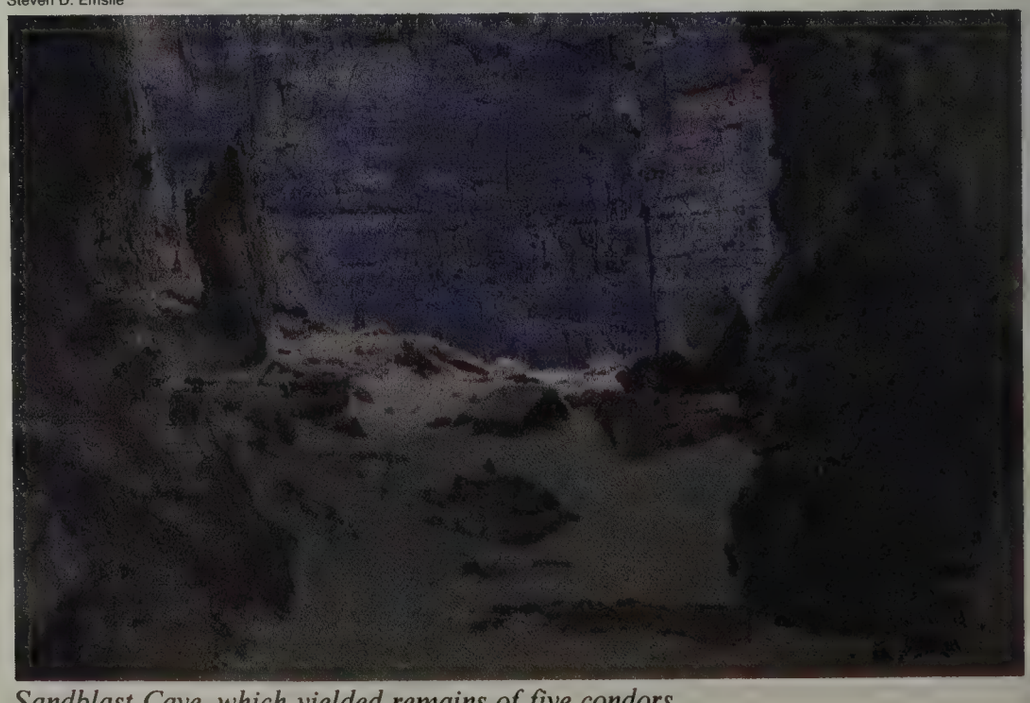
The dates on the condor remains came out as I had expected: all are more than 11,000 years old, but the complete skull from Stevens Cave is more than 12,000 years old. These dates coincide with the disappearance of the megafauna, or large mammals, such as sloths, camels, horses, and mountain goats, from the Grand Canyon. Both climatic change and hunting by early man have been suggested as causes of the decline and eventual extinction of some species of large animals. Condors, which relied on mammal carcasses for food, were doomed along with the Pleistocene megafauna. This hypothesis can be disproved if condor remains that postdate the disappearance of these mammals are ever found. But at the close of the Pleistocene, the large mammals vanished throughout North America, not just in the Grand Canyon. Why, then, did condors not become completely extinct?

The work of Carl Koford, an ornithologist who spent a lifetime studying the habits and life history of the California condor, provides us with most of our knowledge of this bird today. To explain the predominantly coastal distribution of condors within the past two centuries, Koford proposed that toward the end of the Pleistocene, coastal condors were able to shift their diet to aquatic animals and feed primarily on fish and mammal carcasses that washed onto beaches. Condors have been known to feed on beached carcasses of whales and seals. When the large mammals disappeared in North America, only a coastal race of the condor was able to survive because of its proximity to a new source of food or its previous adaptation to this alternative diet.

There still remains the problem of historic sightings of condors in the inland west in the late 1800s. If the condors were primarily coastal birds at that time, what were they doing as far from shore as Arizona and Utah? The answer may lie with the large herds of horses, cattle, and sheep that were introduced in the west in the 1700s. These herds filled a niche left empty by the extinction of the Pleistocene megafauna. With the introduction of these herds, perhaps the condors began to reexpand their range by feeding on the carcasses. Subsequent hunting and the use of poisons by settlers to protect their herds from predators probably drove condors to their current shrunken range in California. There, recent efforts to save the species have concentrated on determining the causes of its high mortality rate. Carcasses poisoned in an attempt to kill predators such as coyotes and carcasses filled with lead shot, which causes lead poisoning when scavenged and ingested by the birds, have been major factors in the condor's downfall. Now, after thousands, or perhaps millions, of years on this continent, the only North American condor is very close to extinction. Ironically, this is happening just as we are learning how this species survived extinction 11,000 years ago.

Steven D. Emslie, a doctoral candidate in zoology at the University of Florida at Gainesville, specializes in the study of fossil birds. The National Geographic Society, the Cave Research Foundation, and the Grand Canyon Natural History Association supported his work in the Grand Canyon.

Steven D. Emslie



Sandblast Cave, which yielded remains of five condors

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Soapy Sam's Logic

A true scoundrel but with redeeming value

by Stephen Jay Gould

History has long arms. The petty people of today will justify their projects by vainglorious comparisons with truly sublime events of the past. Thus, Marx proclaimed in introducing his treatise on Louis Bonaparte (likened by his boosters to the original Napoleon) that all great events occur twice in history—the first time as tragedy, the second as farce. Compare Son of King Kong on the sterile World Trade Center with the grand original, swatting airplanes on the art deco tower of the Empire State Building; or Dracula five, six, and seven (in gory colors) with Mr. Lugosi's old-world manner and accent.

I have just encountered a remarkable example of this pairing in one of the original reviews of Darwin's *Origin of Species*, the long account in the prestigious *Quarterly Review* (July 1860, pages 225–64). The article, by tradition, is unsigned, but no one could have mistaken the style (the *Quarterly Review* guessing game was a great intellectual diversion in Victorian England, comparable perhaps to finding "Nina" hidden in Hirshfield's sketches or trying to figure out what Steinberg means)—so I shall leave you guessing for a page or two.

The farce, in this case, is one of the nastiest and phoniest arguments I have ever read. The reviewer accuses Darwin of supporting racism by dwelling upon the supposed fact that slave species of ants are black!

> There seems to be no limit here to the exuberance of his fancy, and we cannot but think that we detect one of those hints by which Mr. Darwin indicates the application of his system from the lower animals to man himself, when he dwells so pointedly upon this fact that it is always the *black* ant which is enslaved by his other colored and more fortunate brethren. "The slaves are black!" (p. 254).

He then proceeds, by a standard trick of rhetoric, to indict Darwin for things he doesn't say but which, the reviewer conjures, he might say:

> We believe that, if we had Mr. Darwin in the witness-box, and could subject him to a moderate cross-examination, we should find that he believed that the tendency of the lighter-colored races of mankind to prosecute the negro slave-trade was really a remains, in their more favored condition, of the "extraordinary and odious instinct" which had possessed them before they had been "improved by natural selection" from Formica Polyerges into Homo.

As supposed evidence for this remarkable accusation, the reviewer cites a totally different comparison made by Darwin between humans and other animals:

> This at least is very much the way in which he slips in quite incidentally the true identity of man with the horse, the bat, and the porpoise—[now quoting from Darwin] "The framework of bones being the same in the hand of a man, wing of a bat, fin of a porpoise, and leg of the horse, the same number of vertebrae forming the neck of the giraffe and of the elephant, and innumerable other such facts, at once explain themselves on the theory of descent with slow and slight successive modifications."

Every part of this argument is phony in logic, false in fact, and nasty in concept. First, and most decidedly, Darwin makes no point whatever about the color of slave species (most ants are black, after all). I have checked through the Darwin concordance (Cornell University Press, 1981) for every use of the words *black* and *slave* and can find no meaningful conjunction. The reviewer subtly and maliciously misquotes Darwin's line to imply that the black color of slave ants is interesting in itself and worthy of emphasis. He then places an exclamation point inside the quotation and ends the citation there—"The slaves are black!" But, in Darwin's text, the sentence continues and has no exclamation point. It presents a simple and neutral description within a factual paragraph: "The slaves are black and not above half the size of their red masters, so that the contrast in their appearance is very great." Darwin never again, and in no other context, mentions the color of slave ants. He does not "dwell so pointedly" upon it; he does not say, "it is always the black ant which is enslaved," for this sentence describes but one instance of a common phenomenon among ants.

Second, the indictment for validating human institutions by animal analogies is patent and vicious nonsense. The reviewer justifies it, in the absence of any explicit comparison of ants and humans from Darwin, by quoting a line about similarity of *anatomical* structure between humans and other *vertebrates*. But Darwin's comparison is wholly appropriate, for the bones are homologous (similar by descent from a common ancestor). This passage is a non sequitur as supposed evidence for the reviewer's charge. Moreover, ants are not on an evolutionary lineage leading to vertebrates, so no comparison could be made, despite the reviewer's fanciful statement about transforming *Formica* into *Homo*, the African slaver.

If you have not guessed by now, the reviewer is none other than the butt and bugbear of Darwin's opponents—Bishop Samuel (Soapy Sam) Wilberforce, the man who got the short end of the stick (the hook of the cane, the blunt end of the

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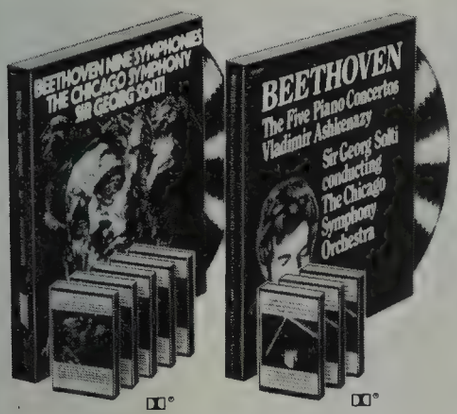
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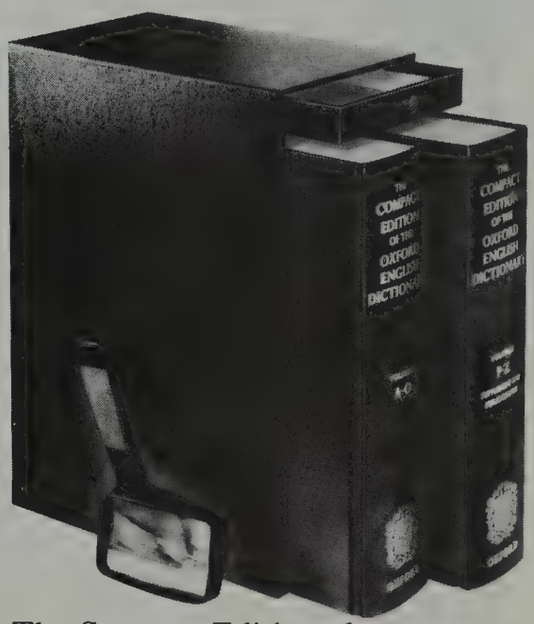

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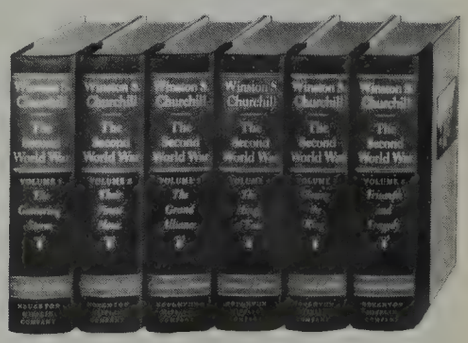

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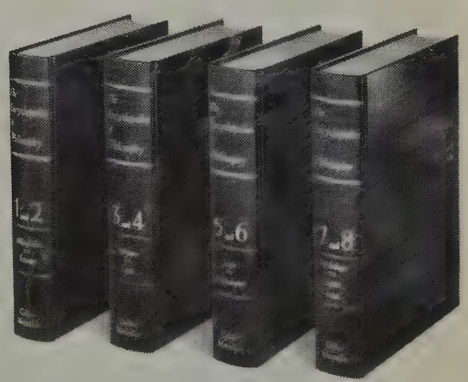

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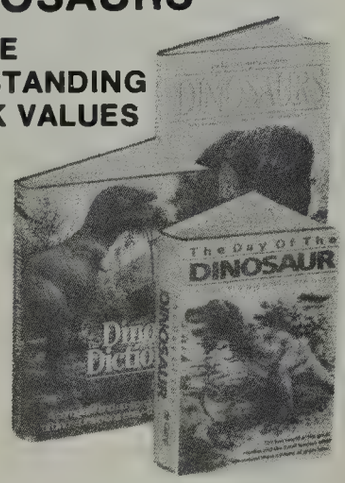

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Antislavery medallion by Josiah Wedgwood I

mallet—choose your own metaphor) in that most famous public moment of the entire debate: the British Association Meeting at Oxford in 1860, when T.H. Huxley skewered the pompous and orotund cleric by dismissing his ridicule and announcing that he would rather have an ape for a grandfather than a bishop who would use oratorical gifts for deception and perfidy. (Next month's column will tell you why this "standard" version of Huxley's victory contains about as much truth as Wilberforce's characterization of Darwin.)

You may not know—and I now expose the tragedy before the farce—that Soapy Sam was the son of William Wilberforce, a hero of abolition and the man most responsible for ending Britain's slave trade. That Samuel would invoke the prestige of his father's great achievement, using his family name by proxy to score a cheap and craven point against Darwin, strikes me as a fine example of Marx's contention about repeated events in history.

Samuel's rhetoric is doubly ugly when we understand Darwin's own views on slavery and his family ties with the elder Wilberforce. Darwin's grandfather, Josiah Wedgwood (the great potter who gave his name to the famous ware), struck hundreds of cameos in his kilns, showing a black slave in chains surrounded by the words: "Am I not a man and a brother?" Darwin himself was an active and passionate abolitionist. Some of the most moving passages ever written against the slave trade appear in the last chapter of the *Voyage of the Beagle*:

> On the 19th of August we finally left the shores of Brazil. I thank God, I shall never again visit a slave-country . . . . Near Rio de Janeiro I lived opposite to an old lady, who kept screws to crush the fingers of her female slaves. I have stayed in a house where a young household mulatto, daily and hourly, was reviled, beaten, and persecuted enough to break the spirit of the lowest animal. I have seen a little boy, six or seven years old, struck thrice with a horse-whip (before I could interfere) on his naked head, for having handed me a glass of water not quite clean . . . . And these deeds are done and palliated by men, who profess to love their neighbors as themselves, who believe in God, and pray that his Will be done on earth! It makes one's blood boil, yet heart tremble, to think that we Englishmen and our American descendants, with their boastful cries of liberty, have been and are so guilty.

I read Wilberforce's review as part of ny research for next month's column on iis famous confrontation with Huxley. My problem as a scholar has always been ny Will Rogers complex—an inability to dislike anyone after reading his works. I nvariably find some redeeming value, ome unnoticed complexity, some honest assion. Through the years, these columns ave tried to resurrect some of the most otorious fools (Burnet on a young earth, r Buckland on Noah's flood) and cranks Gosse on Adam's navel, or Thayer on lamingos and sunsets) of conventional accounts. But in Wilberforce, my geniality as met its match and succumbed in lames. I don't know that I have ever read n argument more slippery, more dishonst, than his on Darwin. That he invested hese calumnies in prose so ludicrously urple (admittedly by modern tastes more pare and economical than his own) can nly add insult to injury. Yet, as I read, I detected something of value for this forum. I liked Wilberforce himself no better; I found no strength at all in his claims. But I did recognize that the internal logic of his argument rested upon a common misconception that remains a major stumbling block to understanding Darwinian, and all manner of historical, argument. A précis of Wilberforce's review might therefore illuminate a problem that still presses upon us. Besides, I'd like to get some use out of that S.O.B.

Wilberforce begins with the classic setup of rhetoric: fulsome praise for Darwin accompanied by protestations of the pain that will wrack Wilberforce for criticisms forced upon him by necessity. "The essay is full," we learn, "of Mr. Darwin's characteristic excellences . . . told in his own perspicuous language, and all thrown into picturesque combinations that sparkle with the colors of fancy and the lights of imagination" (p.226). Nonetheless, he laments later: "We grieve to charge upon Mr. Darwin this freedom of handling facts, but truth extorts it from us."

Wilberforce cranks his nastiness up slowly and then lets it cascade. The first twenty-five pages present a standard critique of the *Origin*, nothing new, but nothing egregious either. Then Wilberforce begins his rhetorical barrage in earnest. He begins with ridicule, attacking evolution as absurd for invented claims never made by Darwin—for example, this lovely passage on our supposed descent from fungi:

> If Mr. Darwin can with the same correctness of reasoning demonstrate to us our fungular descent, we shall dismiss our pride, and avow, with the characteristic humility of philosophy, our unsuspected cousinship with the mushrooms.

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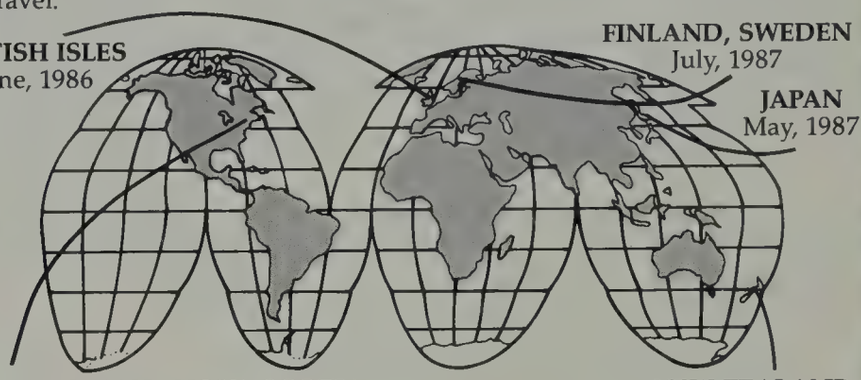

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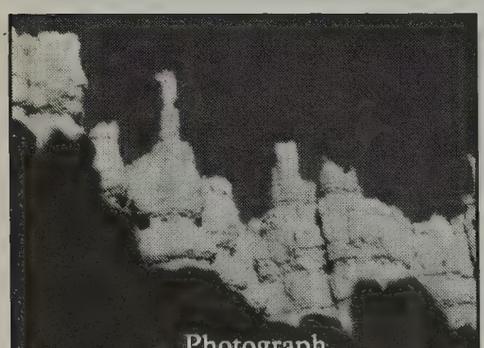

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Wilberforce then moves on to personal attack, accusing Darwin of carelessness, of dogmatism, and finally of dishonesty. On page 250, we find the first summary of charges:

In the name of all true philosophy we protest equally against such a mode of dealing with nature, as utterly dishonorable to all natural science, as reducing it from its present lofty level as one of the noblest trainers of man's intellect and instructors of his mind to being a mere idle play of fancy, without the basis of fact or the discipline of observation .... We cannot open the august doors of the venerable temple of scientific truth to the genii and magicians of romance.

Terrific line, that last, but Soapy Sam is only warming up. By page 253, Darwin's book is an "utterly rotten fabric of guess and speculation"; and, on page 254, "most dishonorable and injurious to science."

Wilberforce now shifts to his own turf of religion and closes in for the kill. He starts again with praise and protestations of affection and respect:

Mr. Darwin writes as a Christian, and we doubt not that he is one. We do not for a moment believe him to be one of those who retain in some corner of their hearts a secret unbelief which they dare not vent; and we therefore pray him to consider well the grounds on which we brand his speculations with the charge of such a tendency.

(So much for anyone who thought that Joe McCarthy was the first since Torquemada to ask the accused when they stopped beating their spouses.)

By page 263, Darwin receives another epithet: "That Mr. Darwin should have wandered from this broad highway of nature's works into the jungle of fanciful assumption is no small evil." And finally, on page 264, we learn that evolution "is the frenzied inspiration of the inhaler of mephitic gas." Well, I never knew I had an evil, heretical drug addict for an intellectual hero!

In and around all this rhetoric, Wilberforce does actually present an argument. It proceeds in three parts and includes a competent but standard critique of Darwin's evolutionary views. (Wilberforce won a first-class degree in mathematics and was, presumably, no dummy.)

In the first part, Wilberforce attacks Darwin's factual claims. He emphasizes three arguments (where Darwin confessed his own weakness): limitation of variation within a rigid "sphere" about the modal form, so that dogs might produce fox terriers and Saint Bernards, but never cats (see my column of June 1985 on Fleeming Jenkin's classic presentation of this argument); missing data in the fossil record;

nd sterility of hybrids as evidence for nbridgeable gaps between species.

The second part criticizes Darwin's eneral arguments. To choose but one example, Wilberforce recognizes—and here grant him some credit, for not everyone id—that Darwin's strongest claims for volution invoked imperfect structures nat recorded historical pathways of decent in their lack of optimality (panda's humb and flamingo's smile of earlier essays in this series).

Wilberforce replies, first of all, that natral selection is not a cruel and inefficient gent of change, acting through copious ain and voluminous death—as Darwin epicted his own mechanism—but a diine device for maintaining the purity of reated forms by eliminating misfits: "In his law we see a merciful provision gainst the deteriorations, in a world apt deteriorate, of the works of the Cretor's hands" (p. 233). We are not told hy the Creator built a world so subject to ecay.

Wilberforce then insists that features of orm and color must be essential aspects f created perfection (p. 252–53), though Darwin identified some as vestiges of inheritance, perhaps once useful but now ithout important function. It must be so, for organisms are only the incarnated ideas of an infallible deity. We know this (page 259)

by declaring the stupendous fact that all creation is the transcript in matter of ideas eternally existing in the mind of the Most High—that order in the utmost perfectness of its relation pervades His works, because it exists as in its center and highest fountain-head in Him the Lord of all.

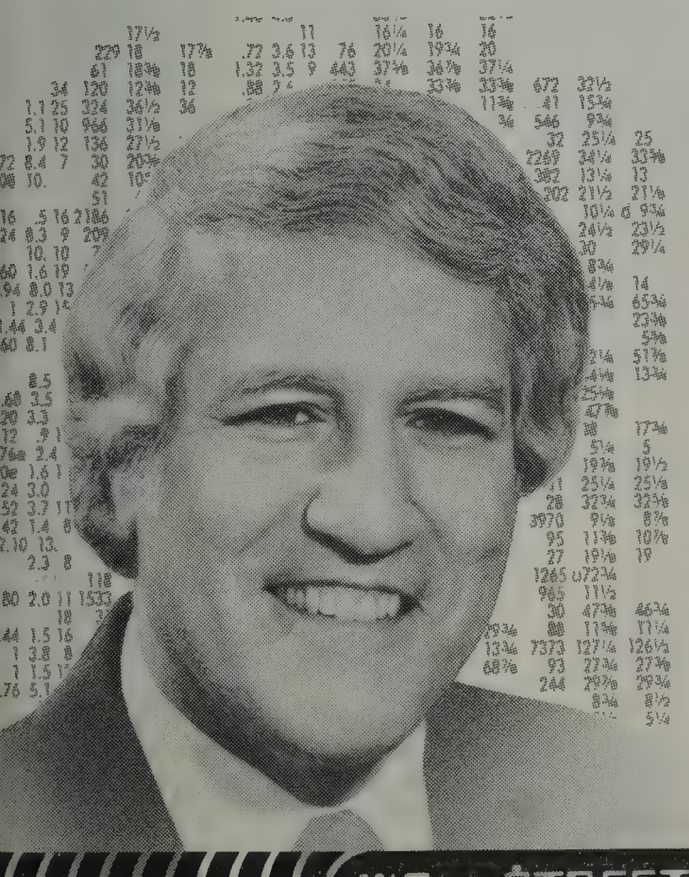
As we work through Wilberforce's critiques,we finally come to the bottom line that, in the end, has always motivated the passion surrounding this debate from Wilberforce to William Jennings Bryan to Jerry Falwell—what T.H. Huxley called in the language of his day (but meaning all of us), "Man's place in nature." For Wilberforce never doubted that the human mind at least had no place at all among the material objects of brute nature:

Man's derived supremacy over the earth; man's power of articulate speech; man's gift of reason; man's free-will and responsibility; man's fall and man's redemption; the incarnation of the Eternal Son; the indwelling of the Eternal Spirit [quite a list!]—all are equally and utterly irreconcilable with the degrading notion of the brute origin of him who was created in the image of God, and redeemed by the Eternal Son. . . . Nor can we doubt, secondly, that this view, which thus contradicts the revealed relation of creation to its Creator, is equally inconsistent with the fulness of His glory (p. 258).

We come finally to the third part of Wilberforce's critique—his attack on Darwin's style of reasoning. In short, Wilberforce brands Darwin as an idle speculator, summarizing his charges in my favorite line of flatulent grandiloquence (properly unsplit infinitive and all):

He who would see the venerable features of Nature must not seek with the rudeness of a licensed roysterer violently to unmask her countenance; but must wait as a learner for her willing unveiling (p. 260).

Over and over again, with increasing emphasis on every page, Wilberforce accuses Darwin of leaving the strict path of experiment and observation for the fictional fancy of pure speculation. Thus, Darwin has substituted "the spasmodic fluttering flight of fancy for the severe conclusions to which logical accuracy of reasoning had led the way " (p. 231). He has abandoned "the stern Baconian law of the observation of facts" (p. 239) and proceeded instead "on the merest hypothesis, supported by the most unbounded as-



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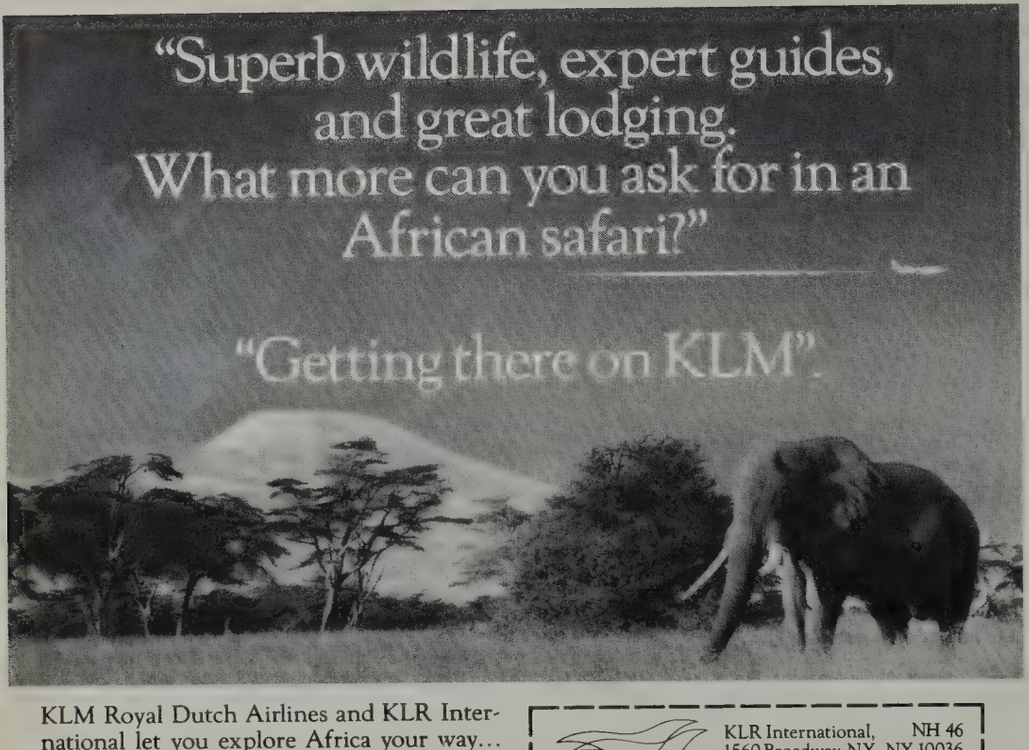

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sumptions" (p. 248) to produce "this flimsy speculation" (p. 264) called natural selection.

Wilberforce's documentation of this charge is as dishonest as ever. Darwin's treatise is largely a recitation of undoubted facts (marshaled to support a theoretical argument of course, but facts nonetheless). But Darwin also conjectures, although rather rarely, about possible modes of historical transformation. He is always careful, in these uncommon passages, to label his argument as pure hypothesis by adding such appropriate phrases as, "we might suppose that . . . ."

Wilberforce simply ignores the factual compendium and tries to turn Darwin's honest admissions against him by depicting the entire book as a list of speculations. He egregiously selects every one of these passages (not many, for they consume but two pages) and ridicules Darwin in summation (p. 249):

> What new words are these for a loyal disciple of the true Baconian philosophy?—"I can conceive,"—"It is not incredible,"—"I do not doubt"—"It is conceivable."

He then cites a passage from Adam Sedgwick, Darwin's teacher in geology and, later, opponent in biology, as though it discredited Darwin's style of science:

> Analysis, [says Professor Sedgwick,] consists in making experiments and observations, and in drawing general conclusions from them by induction, and admitting of no objections against the conclusions but such as are taken from experiments or other certain truths.

A fine definition of "analysis," but not of science itself, a broader activity including "synthesis" and other modes of reasoning. Wilberforce again follows his favorite art of the half quote.

Nonetheless, despite Wilberforce's grossly distorted argument, we must admit his basic claim about Darwin's reasoning. Darwin does not advance his theory of natural selection either as a conclusion drawn from pure observation or a deduction proved by repeated and controlled experiment. If all scientific conclusions must have such defenses, then Darwin's theory is seriously wanting.

Small notions may be affirmed by simple observation. (Early in my career, I proved that not all members of the snail family Siliquariidae had a flat embryonic shell, as previously assumed. I did this by finding a rounded embryonic shell in a species previously unrecorded. I just plain saw it—and photographed it. While I took considerable pride in this genuine discovery, I could scarcely advertise it as earth-shaking.) Truly large theories, compre-

nensive world views such as natural election, are not just seen or derived by experiment. Their defense must include a good deal of observation and manipulation if we want anyone to pay attention, but arguments must extend well beyond. Darwin, after all, was providing a new foundation for all biology.

Experiment tends to be a conservative procedure in science, a way of testing ideas derived in other ways. Natural selection is one of those "big ideas" that we ask observation and experiment to affirm (or reject). We cannot rightly insist, as Wilberforce did, that natural selection emerge only from observation and propose nothing beyond what observation has already affirmed, for we would then be asking that a method for testing ideas also be the only source of their generation—an impossible circle that would bring all thought to a grinding halt.

The structure of Darwin's argument rests upon two types of reasoning that Wilberforce disparaged as speculation. First, Darwin's central statement—that natural selection produces major transformations over millions of years—is based on analogy, not observation. Darwin presents copious facts for small-scale, artificial selection as practiced by humans: improvement of crops, production of numerous breeds of pigeons and dogs. The extension to millions of years and major effects is an extrapolation subject to the objection that pigeons are always pigeons and that artificial selection has strict limits imposed by boundaries of permanently created types.

Second, Darwin often imposed his theory upon imperfect evidence to make sense of observations that, in their literal appearance, did not support natural selection. Most notably, he explained gaps in the fossil record by arguing that natural selection predicted continuity, and that geological evidence must therefore be even more imperfect than we had realized—much like a book with only a letter or two preserved for each page.

"Speculation" is a loaded word, since its vernacular meaning usually includes an unstated adjective before the noun—"vain," "fatuous," or "unsupported," for example. Yet I think we must admit that any theory as comprehensive as Darwin's will include many important parts fitting within the logical structure of a general argument, but not resting upon completed observation and experiment—what any rhetorician of Wilberforce's style and skill will brand as "speculation."

What then is the difference between Darwin's unproved components and speculation that does merit the opprobrium of our vernacular? The criteria for proper separation must be fruitfulness and testability. Vain speculations go nowhere. They emerge from personal preference or the inspiration of an armchair, not from deep thought about puzzling phenomena. They may be clever, exciting, titillating; but they either suggest no way to obtain evidence for their test or may even be untestable in principle. Fruitful ideas, on the other hand, burst with intrinsic suggestions for observation and experiment—action that may require their prompt rejection. Fruitful ideas also lead to other testable insights; vain speculation turns in upon itself.

As one consequence of writing these columns for more than a decade, I have become a sounding board for many private theories about puzzles in science. I have received hundreds of letters over the years, full of passion and conviction about the only possible solution to problems as diverse as the origin of life and the evolutionary meaning of cold sores. Some are clever, elegant, and no doubt, correct; others are wild and silly. If I have gained any general impression from this interesting

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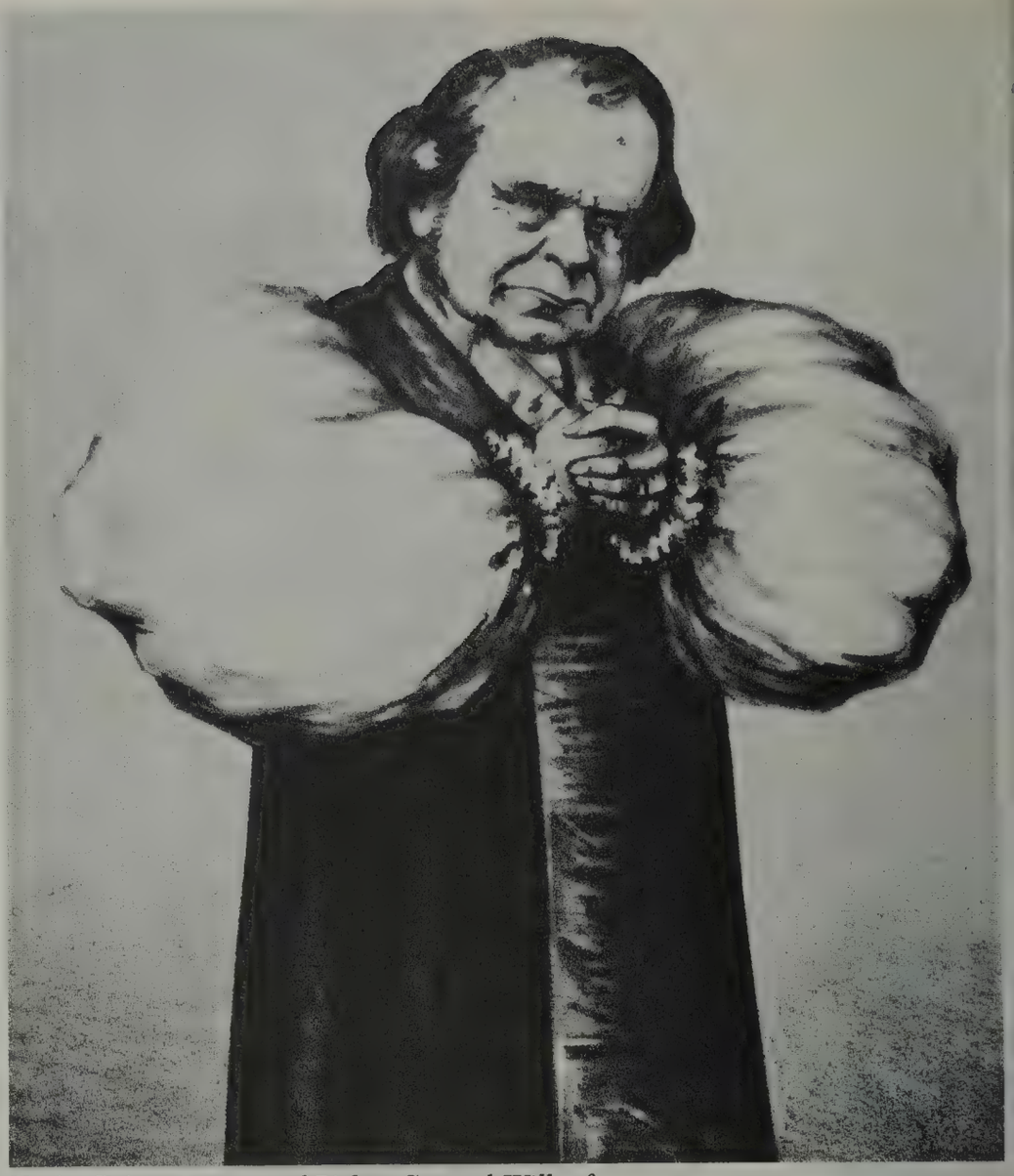

Vanity Fair *caricature of Bishop Samuel Wilberforce*

correspondence, the message, I fear, is distressing (for me at least). So many creative people have not grasped the most basic principle of science as fruitful activity—the criterion that separates Darwin's ideas from Wilberforce's ridicule. So many people think that an idea becomes true or probable by their very cleverness in devising it. They tell me that their primate theory must be true because it sounds so right. They have missed what any good scientist knows in his bones: that fruitfulness in action, expressed as testability in practice, separates the good idea from the idle speculation. Most of these private theories stop where the scientist begins—the devising of a plan for action.

If Darwin excelled at separating useless speculation from fruitful theorizing, he also deeply understood that the testing of historical hypotheses could not always proceed by canonical methods of direct experiment and repetition. After all, historical events occur over millions of years, and their complexity confers uniqueness with no possibility for repetition (we cannot re-create dinosaurs in the laboratory to test various ideas about their extinction). Darwin used different methods, appropriate for historical inquiry, to test the theory of natural selection. Thus, even if he had tried honestly to understand, Wilberforce might not have grasped Darwin's method, tied as he was to exclusive views about pure observation and experiment as hallmarks of science.

Darwin knew that he could not observe the origin of new species directly, much less major evolutionary trends in lineages—for these events take too much time compared with our paltry life spans. Darwin argued that such historical hypotheses could be judged by seeking concordance of pattern among large sets of independent criteria. If all diverse sources of evidence pointed to the same result (and excluded all others that could be devised), then events not directly observed, and not repeatable by experiment, might be validated by concordance of independent criteria. Darwin wrote to J.D. Hooker in 1861:

> Change of species cannot be directly proved . . . . The doctrine must sink or swim

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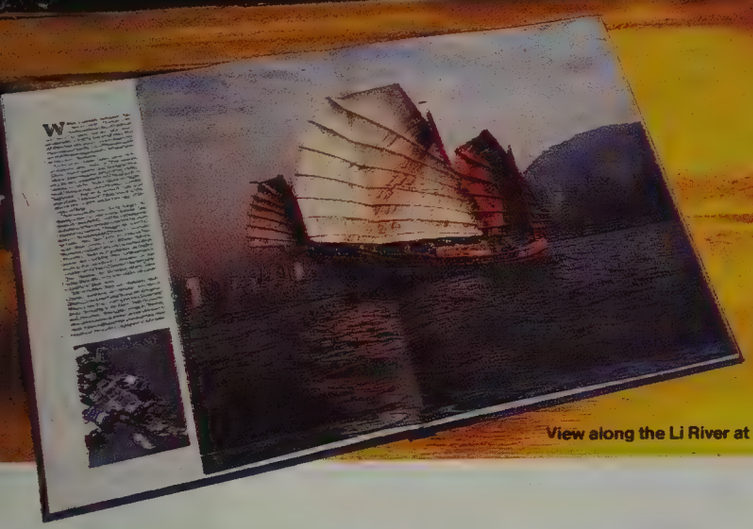

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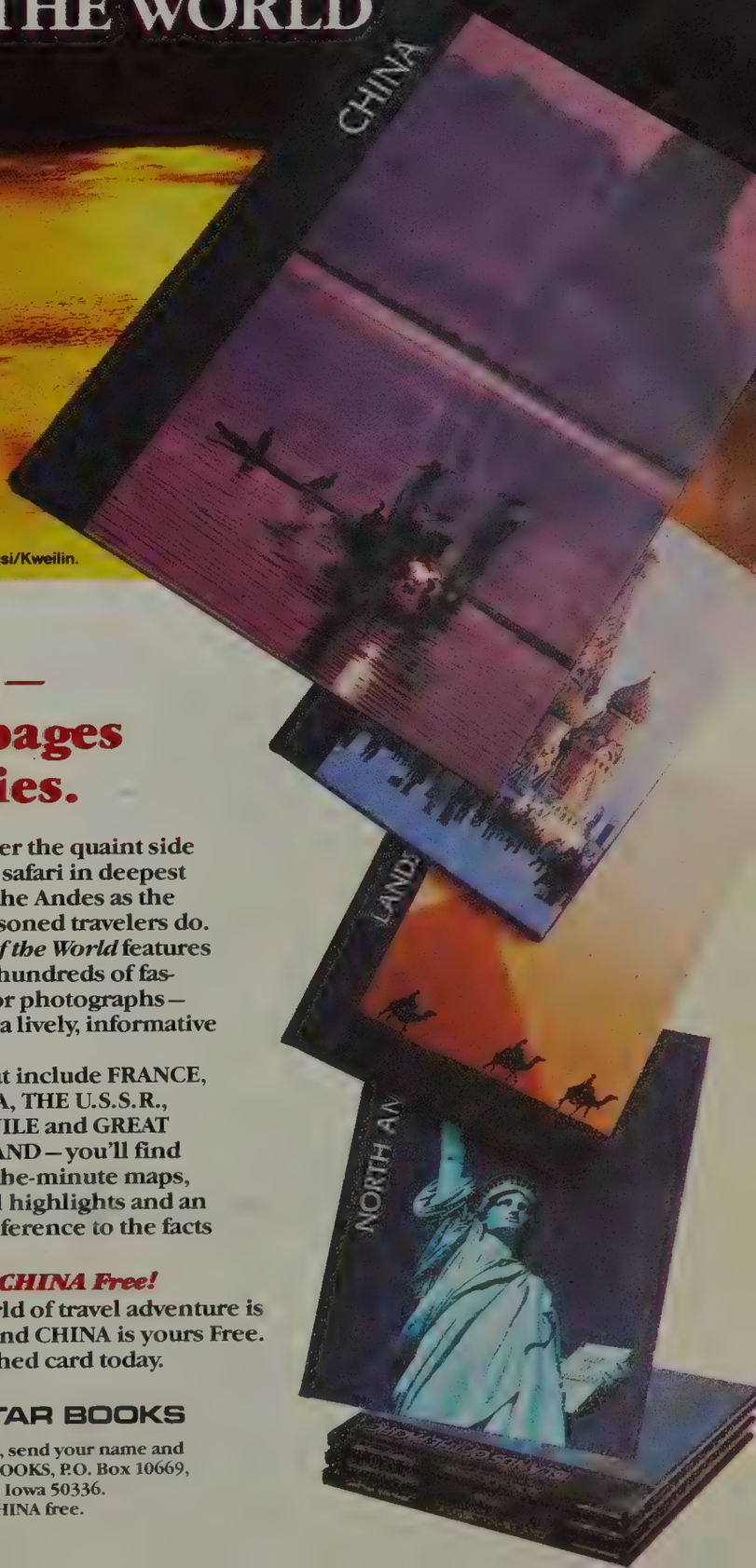

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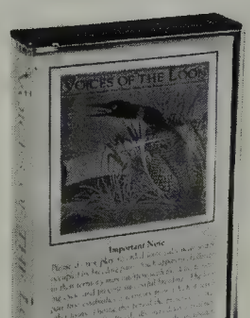

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according as it groups and explains phenomena. It is really curious how few judge it this way, which is clearly the right way.

Speaking more explicitly about natural selection, he wrote in his longest work, *Variation of Animals and Plants Under Domestication* (1868):

> This hypothesis may be tested—and this seems to me the only fair and legitimate manner of considering the whole question—by trying whether it explains several large and independent classes of facts; such as the geological succession of organic beings, their distribution in past and present times, and their mutual affinities and homologies. If the principle of natural selection does explain these and other large bodies of facts, it ought to be received.

Thus, Darwin's speculations were fruitful ideas, testable by the historian's method of concordance among independent criteria. Some were wrong; many were right. But at least Darwin told us how to find out.

William Whewell, a great philosopher of science and Darwin's contemporary, thought hard about modes of testing in science and affirmed Darwin's view about historical hypotheses in his two-volume *Philosophy of the Inductive Sciences Founded Upon Their History* (second edition, 1847). He argued that strongest confirmation arose when hypotheses explained facts of several different, and apparently independent, kinds under the same rubric—particularly when these facts played no role in forming the hypotheses, but arose later to challenge any available explanation (consider, for example, the success of evolutionary theory in making sense of biochemical data, unknown in Darwin's century). Whewell called the process "consilience of inductions":

> Accordingly the cases in which inductions from classes of facts altogether different have thus *jumped together,* belongs only to the best established theories which the history of science contains . . . . I will term it the *Consilience of Inductions.*

Whewell, a conservative Anglican, later banned Darwin's *Origin of Species* from the library of Trinity College, Cambridge, where he was master. Darwin, perhaps, had been too good a pupil in understanding the consilience of induction. For what greater blow can a man suffer than the proper use of his own arguments in an alien context? Which makes me wonder all the more what the ghost of William Wilberforce thought about his son Soapy Sam and the black ants.

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Staying Alive

by George M. Woodwell

If we survive the bellicosity and fiscal madness of these latter years of the twentieth century and have the chance to look back from the first moments of the twenty-first century, we might find in the decades just passed, a series of major transitions in the course of science and human affairs. The century and more of the great naturalists and their voyages of discovery yielded to the time of radioactivity, physics, and bombs, and to the illusions that

THE MACHINERY OF NATURE, by Paul R. Ehrlich. *Simon and Schuster, $18.95; 320 pp., illus.*

the control of physical force brings to politics. And that was followed by extraordinary advances in controlling human disease. Death rates dropped while birth rates continued high, and human populations soared, bringing political frictions on a scale never before seen. Some in this rapidly changing world grew wealthy, while nearly all aspired to wealth, and avarice thrived. Public funds were squandered on war and preparations for war while changes in the earth itself, wrought by the numbers and intensity of the activities of people, raised questions as to whether the biosphere was at hazard, about to be changed beyond the limits experienced in any era since *Homo sapiens* emerged as a species. The thought was a new one, complicated, controversial, and not easily incorporated into governmental functions, attuned over so many years to the thought that mere physical force assured political sway. Suddenly, at least as measured in the time of governments and of human memories, the questions turned from war and profits to how the world works. The old rules seemed to be crumbling before a set of abstruse issues discussed by a small group known as ecologists. What is it that keeps the planet habitable for large numbers of people?

Few think or speak or write on this topic more incisively or comprehensively than Paul R. Ehrlich, whose latest book takes us on a modern tour of discovery. The subject is the earth's living systems, how they came to be and how they work. The theory is Darwinian evolution and its contemporary elaboration into such subjects as coevolution and island biogeography. The new dimension is further insight into nature: where did all the plants and animals come from and why do we need them? Woven throughout the text is the simple, clear message that the cost of ignorance and neglect of this most elementary set of insights is biotic and economic impoverishment equal in its consequences over the years to the instant devastation threatened by war.

Ehrlich is an evolutionist, delighting in discovering and revealing the endless intricacies of structure and behavior that exist far out at the very ends of the branches of the evolutionary tree. He is also a field biologist, exploring the details of the life history, genetics, evolution, and distribution of butterflies on Jasper Ridge in Palo Alto, California, and in the mountain meadows of the Rocky Mountain Biological Station in Colorado. He spins his knowledge, the product of years of research by Ehrlich and his students, into splendid, clear statements as to why it is that broadly toxic substances, such as DDT used as insecticide, often make new pests without controlling the old.

His personal, detailed approach is open and generous to the many colleagues who have shared the intensity of Ehrlich's pleasures in these researches into nature. It is also earnest in conveying the sense of de

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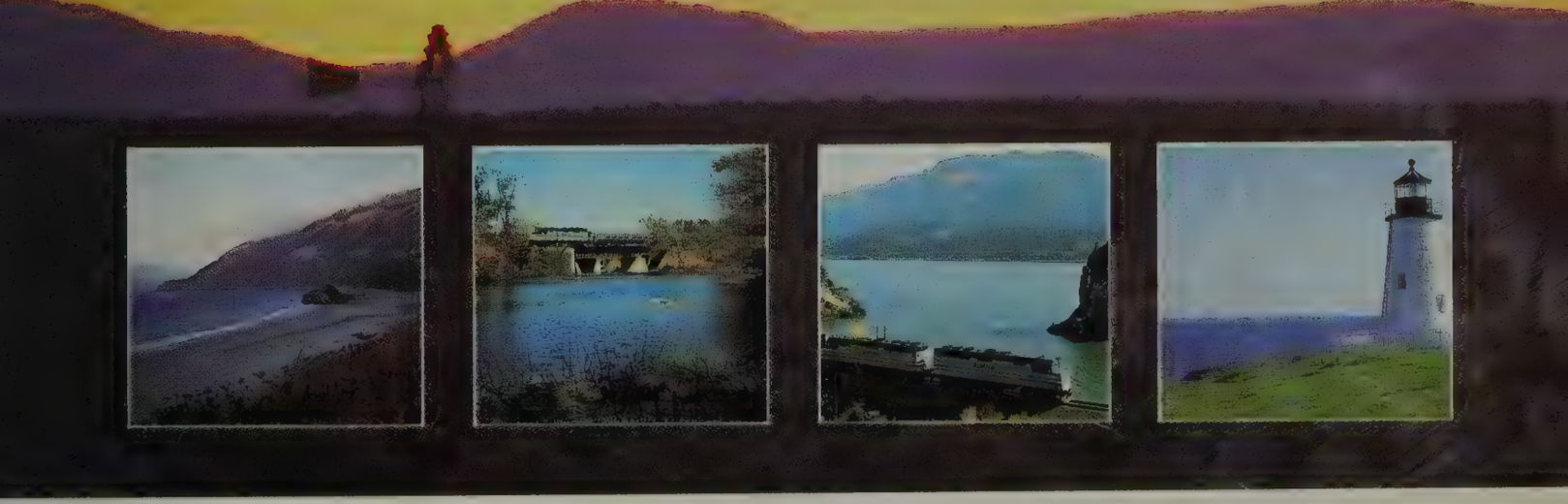

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spair that field biologists share in watching the callous destruction of the earth's primary systems for support of life.

There is no better, more readable elaboration of the evolutionary approach to ecology. Ehrlich and his colleagues have been among the most aggressive and effective exponents of what some might see as a reductionist's approach to the development of a general theory governing the structure and function of natural communities. No such theory has emerged yet nor is one proposed or elaborated here. But the elements of progress, slow and painful as they have been, are set forth with classical examples and lucid explanations. The point of reference in all these studies is the population, the group of individuals within a species; it is seldom the community or the ecosystem. The reasoning is sound: evolution acts on such units, not on communities.

Two elements of progress are important. The first is that organisms evolve together and influence one another progressively, ultimately evolving mutual dependence and the attributes of communities. Biologists puzzle over the various ramifications of these dependencies, including the extraordinary and not thoroughly explained evolution of the social insects. But interspecific coevolution has been one of Ehrlich's special interests and was explored earlier by him with botanist Peter Raven. The details, lavishly supplied here, form part of the basis for recognizing communities and for explaining how communities have reality and can so easily be irreversibly impoverished.

The second element has its origin in Darwin's recognition of the differences in the richness of fauna and flora among islands of different sizes. This observation has been examined in detail by biologist David Lack and, more recently, by others exploring the more systematic and quantitative analyses offered in *Theory of Island Biogeography,* by Robert H. MacArthur and Edward O. Wilson (Princeton University Press). The quantitative approach to the migration and extinction of species has spawned research and strong support for Ehrlich's view that there is no way to retain the earth's biotic diversity without retaining very large areas as reserves. Recognition of this fact has come extraordinarily slowly, and further awareness of the urgency, the consequences of failure, and the need for solutions have come even more slowly. The areas required are so large as to force a reappraisal, and perhaps a redesign, of the possibilities of industrialization. But that is beyond this book, which offers an unusual and delightful series of insights into the problem as seen through the eyes of one of the world's most perceptive and articulate ecologists. Proposed modifications of land use to accommodate some of the realities of life appear in an analysis of the Serengeti Plain. With its unique populations of plants and migratory grazing animals, the Serengeti could provide more protein, with minor human management of natural ecosystems, than can be gleaned from sedentary modern agriculture using intensive management supported by high-levels of fossil energy.

Ehrlich has shown in his powerful and scholarly book that the naturalist's contributions to intellectual and political progress survive and that the push toward quantitative detail and theory in science need not obscure the comprehensive lessons of history and of ecology. The lesson here is that while we fear the ultimate destruction of a nuclear cataclysm, we are simultaneously developing a series of apparently lesser problems whose cumulative effect on the human lot is equivalent to the devastation of war. The tragedy is that the impoverishment is rapid, largely irreversible, and ignored, or, worse, denied by many scholars and most political leaders. There lies the subject of another book.

George M. Woodwell is an ecologist and the director of the Woods Hole Research Center, Woods Hole, Massachusetts.

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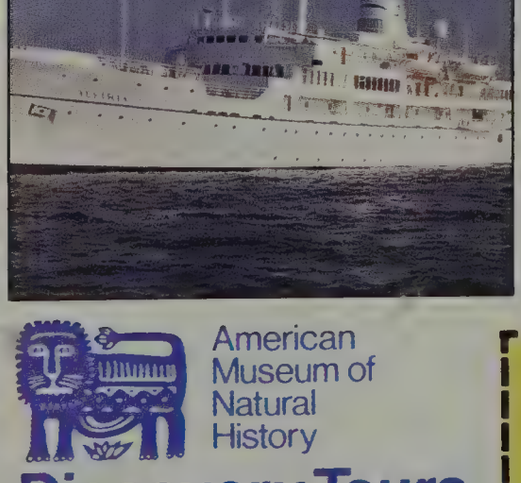

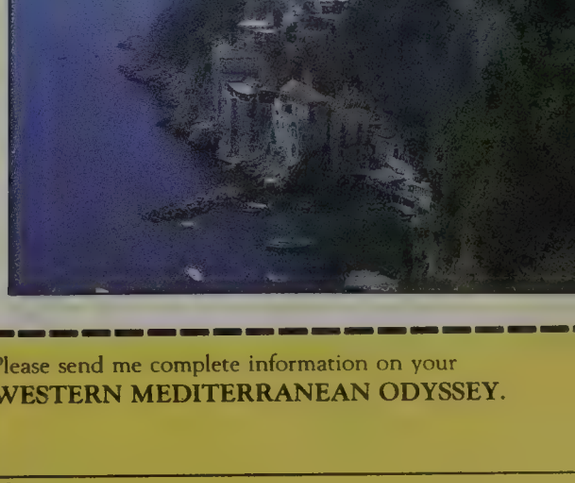

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Combat between stallions involves rearing, kicking, and bites that are often aimed at the rival's legs. Since horses do not fight over territory, competition for females is the most common cause of aggression between males.

Skylar Hansen

Wild Horses of the Granite Range

A stallion's aggression doesn't end with its victory over a rival male

by Carol Cunningham and Joel Berger

Hiking along briskly at an altitude of 8,500 feet, sweat dripping from our brows as we tried to get a good place on the mountain for an overview, we suddenly caught a glimpse of white, polished bone piercing the blue skyline. First, there were the remains of one horse, then two, then three. Looking more closely we counted six carcasses: some were all clean and shiny; but several still had pieces of flesh and hair. These horses had been trapped in a deadly winter snowstorm. We had seen them two years before, alive and well, miles away on the valley bottom.

When we began our study of wild horses in 1979, little was known about environmental or other causes of death, or even about reproduction. Of course, people have been interested in horses for more than 5,000 years. Horses are prominent in lore and literature. Testifying to their popularity are the more than 40,000 books that have been written about them. Shakespeare wrote (in *King Henry V*) about Pegasus, "He is pure air and fire; and the dull elements of earth and water never appear in him. . . . He is indeed a horse, and all other jades you may call beasts." However popular domestic horses are, wild horses are another story. Many ranchers treat them as mongrels of the range. Few books have been written about them, and as of 1985, none had dealt with their biology.

In North America, wild horses may be found in ten western states, on several barrier islands off the Atlantic Coast, and in a few remote areas of Canada. Most, if not all, of today's horses are not the mustangs of yesterday, at least not in the true sense. Mustangs were free-living horses that were the direct descendants of the Spanish stock that arrived in the sixteenth century. Most historians, equid enthusiasts, and scientists agree that today's wild horses stem from animals that were turned loose or escaped from Native Americans or ranchers. As the animals encountered one another and bred, herds grew. No truly accurate figures exist as to what population sizes might have been in the past, but estimates vary from one million to several million animals.

Historically, wild horses were widely

distributed throughout the western and some of the Plains states, including parts of Texas and California's great Central Valley. Most of today's horses live in the Great Basin Desert, an extensive community of plants and animals reaching into nine western states. The region contains about 300 mountain ranges, some as high as 13,000 feet, and is home to an estimated 40,000 to 60,000 wild horses.

Almost all wild horses are found in sagebrush-steppe habitats, where many have small home ranges and move over the same areas year in and year out. Although these areas usually do not encompass more than ten square miles, there are seasonal differences, with horses generally feeding over wider areas in the summer. Most animals travel less than a mile per day to feed and about one-third that distance at night.

Together with feral burros, horses have become members of the controversial fauna of the austere Great Basin. Horses have been accused of fouling water, hastening erosion, competing with domestic livestock, and displacing native species such as pronghorn antelope and bighorn sheep. The root of the issue is that, like all species faced with an abundant food supply and few natural predators or diseases, horse populations increase. While much time and money have been spent debating the factors that should or might influence population levels, we adopted a differen approach. Rather than ask why there ar so many horses, we sought to understan why some horses reproduced more suc cessfully than others. In essence, w asked, what factors control reproduction

In 1979, one of us (J.B.) spent thre months in seven western states looking fo a study site where there were horses but n domestic livestock, where visibility wa unimpeded by trees, and where permis sion for a long-term research projec would be granted by the federal govern ment. If we were to study wild horses, seemed far better to gather informatio through direct observations, rather than t make inferences based on radiotelemetr

Skylar Hansen

A stallion, left, mates with a receptive mare in his harem. Mating with a familiar mare is preceded by a courtship characterized by nuzzling, whinnying, and sniffing and does not involve any of the aggression stallions show toward unfamiliar mares. Two young bachelor males, below, play-fight by biting at each other's forelegs. These mock battles develop fighting skills that in adulthood could lead to serious wounds or, occasionally, to death through blood loss or infection.

Joel Berger

acking. (Many of the people we talked , including ranchers and government orkers, tried to discourage our work. ommonly we heard, "What do ya wanna ow about horses—ask me, I'll tell ya.") ince 1979 our work has focused on horses the Granite Range, a remote 9,000-foot ountain rising abruptly out of the Black ock Desert in northern Nevada. Horses ave been in the Granite Range since at ast 1911, although their origins are ob- cure. One of the more interesting rumors at we encountered in Gerlach, the earest town, was that horses escaped dur- g a train wreck in the Black Rock Desert nd found their way into the adjacent ountains.

Unlike most mammals, horses live in year-round bands, each composed of one or more stallions and a harem (females and young). Almost 90 percent of the Granite Range bands had only a single stallion and some stallions have been with the same harem for at least seven years. Such associations are remarkable. They suggest that some animals are not merely vaguely familiar with one another, but that they know each other very well. These social relationships turned out to be essential elements in reproductive success or failure.

Granite Range animals are similar in many respects to most feral horses and probably to domestic ones as well. For example, all horses generally have gestation periods of about eleven months. Granite horses also experience a seasonal peak in births. This occurs in the spring, although foals may be born throughout the year. We were astonished that a three-day-old winter-born foal withstood temperatures of -13° F and winds exceeding seventy miles per hour. Indeed, foal survival is high—more than 90 percent of the Granite foals lived a year and survival among yearlings was even higher.

But not all populations increase as fast as they theoretically should. Why? What depresses population growth? Except for a few expected foal deaths and animals that died in storms at high altitudes, we were initially frustrated by not being able to identify what other factors (if any) were affecting the population. We had noticed that stallions fought intensely for mares, but that was by no means surprising. Charles Darwin had reported on horse combat, and almost one hundred years before that, in 1769, an observer described a fight to the death between two stallions. Still, we were surprised that more than 95 percent of the adult males in the Granite Range had wounds or scars.

In May 1981 we observed an event that would later influence our thinking. Harry, a six-year-old male without a harem, battled for three days with Moscha, a twenty-one-year-old, whose small harem included two adult mares. The fight was not continuous; Harry incessantly circled Moscha and charged toward the mares, trying to separate them from his rival. Direct combat also occurred, and on at least eight occasions, both animals tried to avoid bites directed at their legs by collapsing on them. The most intense fights are those in which bites are directed at legs, perhaps with the canine teeth playing a role in severing leg tendons. At the end of the contest Harry had traversed about thirty miles, mostly in circling and prancing, and

Below: A stallion (at right) guards a pregnant mare from rival stallions. Right: A three-hour-old foal stands on shaky legs. Although rocky slopes are difficult terrain for foals to navigate, they are preferred birth sites—perhaps because they offer protection from predators.

Both photographs by Joel Berger

Moscha only a few miles less. Moscha stood with his head lowered, too tired to move very far, and Harry directed the harem to another area.

Harry tried to mate with his newly acquired adult females, despite their persistent kicking and attempts to avoid him. This unusual aggression was interesting to us, primarily because we knew that stallions familiar with their mares never forced copulations, but at the time we did not appreciate the biological and evolutionary significance of this behavior.

About six months later, on a cold, blustery November morning, we remarked to each other how strange it was that foals would be born so late in the year. Suddenly we remembered that the mothers of the two new foals had been forcibly mated the previous November. The sexual aggression had taken place during and right after a harem takeover, as had happened with Harry and his females earlier that year. A clear picture of how social factors might affect reproduction was beginning to emerge.

After some 8,000 hours of direct observation to amass our data base, we were ready to release the results. We found that females in bands that experienced takeovers were on the average about half as successful at producing foals as those in stable bands. The ages of females within these bands did not account for our findings, because we compared females of equivalent age categories.

The answer lay in part with the behavior of stallions. In bands whose members have long associated with one another, mating is relaxed. Of the 244 copulations observed between stallions and mares in the same band, all had elements of courtship, including nuzzling, whinnying, and sniffing. In contrast, in thirty-eight instances of mares meeting strange stallions, fourteen resulted in forced copulations. Unlike females that were familiar with their mates, these mares ran from and kicked at the stallions: The most dramatic case involved a female that ran about three miles and kicked at the stallion fifty times although he still managed to mate with her. Clearly, something about unfamiliar females triggered males to respond more aggressively than they did to their own familiar mares.

In mammals as diverse as red howler monkeys, hanuman langurs, African lions, coatis, and several rodents, males kill the offspring of unfamiliar females. Such females are then likely to become sexually receptive, a feature that enables males to father offspring of their own. (The females also benefit by producing offspring sooner than if they had delayed reproduction for another year.) In short, these males increase their evolutionary fitness by reducing the genetic representation of potential rival males and, at the same time, by increasing their own.

Might stallions be expected to gain a similar advantage if the females that they forced to mate were already pregnant? In most studies of wild mammals, gathering data on this topic is problematic because it is difficult to determine pregnancies without handling animals. Fortunately, horses are easier to work with than many species and it was possible to infer pregnancies. Because we observed copulations and knew whether or not females returned to estrus, we were able to predict whether they had conceived and when births were expected. When births occurred at the times we predicted, we felt confident that our behavioral measures accurately reflected whether mares had been pregnant. Our accuracy in predicting pregnancy was poor only for mares in groups experiencing takeovers. In other words, the statistical evidence was overwhelming that something different was happening to pregnant mares that experienced takeovers. They were not giving birth as often as mares in stable bands. The evidence supported the idea that new stallions were diminishing genetic "traces" of rivals by inducing abortions. However, it was also clear that the females themselves may have had something to do with the abortions; some females from bands that were taken over were not forced to mate by the new stallions, yet they, too, aborted. Finally, only females less than six months pregnant aborted. Mares further along in their pregnancies did not. At least one mare was forced to copulate when ten months pregnant. We can only surmise that there are several immediate factors responsible for mare abortions during takeovers. These include physical damage caused by the male during penetration, introduction of disease, stress, and other variables.

According to our hypothesis, in order for male sexual aggression to be adaptive for stallions, they should benefit by siring offspring from the newly barren mare

And, our evidence confirms that this is the case. Within three weeks of the time females were forced to copulate, males courted them and females willingly mated with them. We observed no aggression in either sex. Even though only about 50 percent of the females were able to again support the costs of gestation and bear foals in the next year, the males were successful at diminishing the traces of rival males and subsequently siring offspring of their own. Both outcomes were consistent with the idea that males gain reproductive benefits by forcing copulations on females after band takeovers.

Surprisingly, few studies of horses or other large mammals living in year-round harems have reported the possibility of induced abortions. Are our Granite Range horses unique? We don't think so but let's consider five objections that have been raised concerning our data.

First, induced abortions do not occur in domestic horses, and thus, they should not occur in wild horses. To test this would be difficult. In captivity, mares are fed and often separated from stallions. Their breeding, with its combination of fences, hobbles, and artificial environments, is completely different from breeding in unmanaged, free-ranging situations, and we do not know what biases are introduced when trying to understand natural biological processes.

Second, observations of other feral horses do not substantiate the Granite data. This claim can be readily dismissed. Most of the feral horse studies that have been done were structured very differently from ours. Their designs did not call for fieldworkers living at the study site for long periods of time and making daily observations. Data from other areas have not yet estimated gestation lengths, birth dates, or paternity. Until copulation frequencies are systematically sampled, takeovers actually witnessed, and mare reproductive rates followed over periods of many years, it will not be possible to know whether the Granite data are applicable to other populations.

Third, males cannot force copulations on unreceptive females. This idea has been argued with a great deal of conviction. However, we have seen males force females to mate. Stephanie Tyler and Ron Keiper, whose independent studies of feral ponies in other regions are often quoted, have also hinted at forced copulations. This supports our observations that males try to force mating and that similar events have occurred at locations other than the Granite Range.

Fourth, the Granite population is unusually dense. There appears to be no logical basis for this claim. It's not obvious how density would influence distinctions that stallions make between familiar and unfamiliar mares. Regardless of density, stallions must still associate with females, some of whom will be familiar while others will not. If density affected the frequency of abortions, we would have expected abortions to increase with population size. However, our data do not show this correlation. Finally, the Granite population appears to be no denser than numerous other horse populations.

Fifth, and perhaps of critical importance, is the premise that if the behavior we observed at Granite Range is natural, then other equids should also show it. We agreed, but only anecdotal evidence was available about similar species. Fortunately, new evidence now points to the possibility that socially induced abortions may occur in zebras. Biologist Barrie Penzhorn has shown that in harem-dwelling mountain zebras from South Africa, none of seventeen individually identified

Emory Kristof © National Geographic Society

Below: A stallion typically herds or directs females by extending his head and neck and retracting his ears. Right: A band of horses runs across the sage-and-juniper landscape of the Granite Range—a remote 9,000-foot mountain that rises out of the Black Rock Desert in northern Nevada.

Joel Berger

mares produced foals after band changes. Six or seven would have been expected based on the average foaling rate of the population. Other hints of the abortion phenomenon can be found in plains zebras in East Africa. Thus, our findings may be more typical of harem-living equids than had been previously supposed.

Seven years after we began our research, the Granite population is still increasing, but we are now able to identify some factors that slow its rate of growth. Bands, stable or not, occupying marginal areas reproduce poorly because of low-quality food supply. High-altitude deaths take a small part of the population as do deaths resulting from fighting. Abortion also plays its role, but it diminishes by only 4 to 5 percent the total number of young that might otherwise survive.

While horses are captivating animals with an intriguing evolutionary biology, the controversy over their existence continues. Justifiable concern over population increases has been expressed by environmental, humane, and ranching groups. But in order to find solutions to problems, they have to be identified correctly. Areas where land conflicts occur are occupied by exotics other than horses. Privately owned domestic cattle, sheep, and goats use the same public lands that horses do, and their numbers exceed that of horses by a margin of 4.5 to 1. This suggests that some of the destructive effects attributed to horses might actually be caused by the proportionately greater number of privately owned species. To date, not a single scientific study has demonstrated that horses are the culprits.

Wise management of habitats cannot proceed without information on how ecosystems function in the absence of disturbances. We must set aside areas free of horses, other exotics, and additional forms of disturbance so that a better understanding of ecological dynamics can be gained. Without such knowledge, we will suffer the destruction of a unique ecosystem. If the chief stewards of our public lands are willing to institute policies based on scientific knowledge, rather than on economic rewards, we will all benefit. The Great Basin would have fewer, but plenty of horses; even fewer privately owned exotics; and public lands free from human disturbances. Sadly, the alternative, "business as usual," sanctions the destruction of what John Muir called, "A country of wonderful contrasts, hot deserts bounded by snow-laden mountains, cinders and ashes scattered on glacier-polished pavement, frost and fire working together in the making of beauty." □

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The Children's Fate

If children constituted a nation, it would be the world's largest. More numerous than two Indias, the 1.7 billion youths born

since 1970 will carry the legacy of this century into the next. Yet children have no say in the decisions that shape their prospects. And they pay a disproportionate share of the cost of the ecological and economic disruptions their parents have left behind. Although we wish to leave our children a rich inheritance, we are instead saddling them with an alarming array of debts.

About a quarter of all people on earth today live in industrial countries; but only one child in six grows up in these relatively prosperous environments. All the rest can be found in less developed regions of Asia, Africa, and Latin America. The gap between these "young poor" and "old prosperous" nations will only widen, since nearly nine out of ten babies are born in the nonindustrial world.

What are the possibilities the future holds for these children? For some, an irretrievably changed landscape: Africa's Sahel may be virtually treeless, not even thorny acacias remaining to shelter families and their livestock. For others, painful adjustments to resource scarcities: Sinking water tables will silence irrigation pumps outside Phoenix and Tucson, while families in Beijing will grow accustomed to rationed supplies of drinking water. Unexpected hazards and uncalculated financial burdens await even children in affluent countries, where hundreds of highly radioactive nuclear reactors will require dismantlement and disposal after they generate their last kilowatts. Fortunately, decisions made now on behalf of children can reduce these challenges to manageable size. And as some societies are learning, taking seriously the interests of the next generation often best serves the current generation as well.

Edward C. Wolf

Our generation is leaving the next a legacy of deficits, economic and

ecological. Discounting the future, we live for today as though there were no tomorrow—as though we had no children. Deficits have become an inherent part of our life style. The United States government, traditionally a leader in world economic matters, has incurred more debt since 1980 than during the preceding two centuries. Dozens of Third World countries have run up external debts that they will never be able to repay.

A leading source of growing debt has been the militarization of the world economy. The notion that countries everywhere should be prepared to defend themselves at all times from any conceivable external threat is a relatively modern one. Before World War II, countries mobilized troops in times of war instead of relying on large, permanent military establishments. In the years since the end of the war, the military burden on the world economy has grown enormously.

Global military expenditures in 1985 surpassed the combined gross national products of China, India, and all African countries south of the Sahara. And last year the Third World spent more money on arms imports than on buying grain, indicating that where foreign exchange allocations are concerned, guns have replaced bread.

Economic deficits may dominate the daily headlines, but ecological deficits will dominate our future. Accounting systems signal when a country begins to run up an economic deficit, but they do not indicate when the sustainable-yield threshold of a biological resource, such as a forest, has been crossed. Ecological deficits, such as the loss of tree cover or of topsoil, often go unnoticed until they begin to affect economic indicators. But by that time, excessive demand may be eating up the resource base, converting a renewable resource into a nonrenewable one.

Ecological deficits occur when the demands on a natural system exceed its carrying capacity. If the amount of wood removed from a forest exceeds the new growth, the forest begins to shrink and will eventually disappear. Likewise with a fishery: When the catch begins to exceed the sustainable yield, the fish stocks decline. If the excessive catch continues, the fishery will collapse. If the demand on a system continues to expand after the sustainable-yield threshold has been crossed, the resource base will shrink with each passing year. In the absence of action to correct the balance between demand and sustainable yield, the pace of resource destruction will accelerate, leaving society with little time to act.

When historians analyze this era of debt, they will discover that excessive economic and ecological deficits have similar roots, for they reflect similar values and processes. Occasionally, they are a result of miscalculations. But more commonly they result from a loss of social discipline, from a decision to satisfy today's needs and desires at the expense of tomorrow's—in effect, a decision to "charge it" to our children.

Although similar in cause, economic and ecological deficits differ in their effect. The former do not reduce an economy's inherent productivity. Ecological deficits, however, actually diminish the resource base on which the economy depends. For example, a farmer in debt may lose his farm when the local bank forecloses on the mortgage. But the farm does not lose its productivity; it merely changes hands. If, however, the farmer faces an ecological deficit, losing topsoil through erosion, then the farm becomes worthless and the land must be abandoned.

Of all the excessive demands on the earth's natu-

Nisren Mohd Zaman, age 12, Oman

U.S. Committee for UNICEF

ral systems, that on forests is the most visible. Land clearing for agriculture, firewood gathering, and harvesting by lumber and paper industries are all taking a toll. As of the mid-1980s, every country in Africa is losing tree cover. Indeed, forest deficits are now the rule throughout the Third World. Only South Korea and China appear to be planting more trees than they are harvesting.

At the same time, forests in industrial countries are beginning to suffer from excessive chemical stress. As the use of fossil fuel has expanded over the past generation, the discharge of sulfur dioxide and nitrogen oxides has also grown, as have the ozone levels. Across the northern tier of industrial countries—North America, Europe, and the Soviet Union—air pollution and acid precipitation are now damaging and destroying forests. No industrial country is escaping this destruction, though some, such as Czechoslovakia, Poland, and West Germany, are suffering more than others.

The same demographic forces that are increasing pressure on Third World forests are also multiplying pressures on grassland. With livestock herds growing almost as fast as human populations, grasslands are deteriorating in Africa, the Middle East, the Indian subcontinent, and Central America. In some countries, grasslands deterioration has reached the point where herd liquidation is now the only feasible response.

Throughout most of history, the human demand for seafood did not even remotely approach the sustainable yield of oceanic fisheries. But as our numbers have nearly doubled since midcentury, claims on many fisheries have become excessive. From 1950 to 1970, the world fish catch expanded at 5 percent per year, as fast as, or even faster than, the global economy. This changed abruptly after 1970, when annual growth dropped to 1 percent. Overfishing, which had been the exception, was becoming the rule, and a lead sector in global economic growth began to lag.

Perhaps the most worrisome loss is that of topsoil. Soil erosion is a natural process, but when it exceeds the rate of new soil formation, as it now

does on an estimated 35 percent of the world's cropland, then the land's inherent productivity begins to decline. Topsoil loss, in industrial and developing countries alike, is beginning to affect the economics of food production. Industrial societies can usually offset such a loss with increased fertilizer use, but in some fourteen Third World countries—mainly in Africa—soil loss is reducing land productivity.

Water, too, is becoming scarce in some parts of the world, constraining growth in both agriculture and industry. In most situations, scarcity results from a growth in demand that exceeds locally available supplies. In others, it stems from a reduction in supplies. With deforestation, other losses of vegetation, and land degradation, rainfall runs off instead of sinking into the earth. As a consequence, less water is available to refill underground sources (aquifers) and less returns to the atmosphere via evaporation from the soil and the leaves of plants. The result is lower water tables and, perhaps, less rainfall. Countries experiencing a rapid growth in water demand, diminished aquifer recharge, and a decline in rainfall can find themselves in a water crisis almost overnight.

Whether they occur with forests, soils, fisheries, or water supplies, ecological deficits—like fiscal ones—represent a borrowing from the future. The price for our propensity to live beyond our means will be paid by our children and grandchildren.

The world's economic difficulties—especially the proliferation of unmanageable debts plaguing countries in every region and at every income level—provide ample evidence of ill-conceived policies and misplaced priorities. Enforced austerity nearly always falls most heavily on those least able to bear the burden of a decline in living standards—the poor, and particularly women and children. Ironically, the countries with the brightest prospects are those, like Sri Lanka and China, that have placed the highest priority on improving the lives of just these groups.

Few countries in the Third World have ignited an economic improvement as rapid and broadly based as that now under way in China, one of the few Third World countries that have no external debt to speak of. While many developing and industrial economies have stagnated or declined over the last decade, China's economic expansion has accelerated. Campaigns for family planning, rural health care, primary education, and female literacy in the 1970s laid the foundation for economic reforms in 1978 that boosted the nation's growth rates. At the same time that leaders in Beijing have fashioned policies to slow population growth and push harvests ahead, they have cut the military share of the country's budget by 50 percent.

Even though average incomes in China are still

Deganit Peretz, age 9, Israel

U.S. Committee for UNICEF

lower than in most Third World countries, levels of health and longevity are approaching those in industrial societies. Indeed, the country's birth rate, infant mortality rate, and life expectancy at birth rank much closer to those of the United States than to the remainder of the Third World. Its annual birth rate of 19 per 1,000 population is only slightly above that of industrial countries, and its infant mortality rate of 38 per 1,000 live births is close to that of some American cities. And life expectancy, at sixty-five years, denotes lasting conquest of major childhood diseases. Sri Lanka's infant mortality rate of 37 and life expectancy of sixty-nine indicate equally impressive progress, and this on an average income of scarcely $300 per year.

China's low birth rate has allowed the country to concentrate on providing better opportunities for its children. Ninety-five percent of Chinese children are enrolled in primary school, and the country's 80 percent literacy rate is among the highest in the Third World. Women have perhaps gained most from the advances. Nine girls out of ten are enrolled in school, and Chinese women can expect to live to age sixty-nine, longer than in any other developing country.

Deficits of many kinds plague the world in 1986. We have begun to recognize that Third World debts are not exclusively a Third World concern, and that solutions will require a partnership of debtors and creditors. Similarly, we must recognize the common interests of present and future generations. We must acknowledge that the many fiscal, ecological, and social debts we incur today come at our children's expense. Retiring our debts will require careful thinking about the world we entrust to the next generation.

Lester R. Brown

Once-fertile fields in Ethiopia's highlands may be abandoned in the next

decade, although the land has been under continuous cultivation for many centuries. The exhausted fields provide a dramatic example of a cascading decline in biological and economic productivity. Thoroughly commonplace activities—clearing new fields, gathering fodder for animals, collecting twigs and branches for household cooking—set this decline in motion.

Trees that once blanketed highland hillsides drew mineral nutrients up from deep soil layers, and their leaves returned those nutrients, along with organic matter, to the topsoil. As settlers moved into the highlands in search of farmland, they cleared forests farther and farther from villages, interrupting the nutrient cycles dependent on these trees. With no artificial fertilizer to offset the loss, the plowed fields have inevitably grown less fertile.

As the forests recede, fuelwood becomes a valuable commodity. Men earn cash by selling wood that their wives and children have gathered. In their own homes, families burn animal dung and straw as fuel. With no straw left to protect the soil and no dung with which to fertilize crops, harvests shrink and the soil erodes.

Roughly half the energy used by Ethiopian families goes into baking *injera,* a spongy bread made from teff (the country's traditional staple grain). Women kindle small fires under clay disks called *mtad,* on which they spread the dough. This scene, repeated in thousands of households each day across Ethiopia, exemplifies the bond between fuel and diet. If fuel is scarce, *injera* cannot be baked; but the overcollection of fuel eventually affects the land on which the teff harvest and the *injera,* itself, depend.

Large areas of the highland provinces are already virtually treeless. In these areas, dung and straw are now sold for fuel in village markets. In the village of Debre Berhan, north of Addis Ababa in Shewa Province, donkeys carry eighty tons of dung to market each week. Harvests decline as dung is diverted from its traditional use as a fertilizer. Families earn more from the manure of their oxen than from the sale of marketable crops like teff, because their harvest can supply little more than subsistence needs. Dung, the main fuel supply in villages like Debre Berhan, is also the biggest cash crop from surrounding farms.

If the yearly rains are lower than normal, crop failures are likely. No one is able to save a surplus from one year to the next. When the rains fail entirely, famine threatens. Once-fertile fields yield nothing; the decline has reached its conclusion. According to World Bank ecologist Kenneth Newcombe, "This transition from the first to final stage is in process right across Ethiopia and has reached the terminal phase in parts of Tigrai and Eritrea."

When families can no longer feed themselves or their animals, a massive exodus from rural areas begins. The ecological refugees that lined Ethiopia's few roads and filled feeding camps in the early 1980s were only part of more than ten million Africans that left their homes in search of food, frequently crossing national borders in a desperate quest. Hundreds of thousands of Ethiopians crossed into Sudan. Mozambicans moved into Zimbabwe to escape the guerrilla warfare, ecological deterioration, and social disintegration in their homeland. Mauritanian nomads moved into Senegal and the Gambia, attempting to escape the Sahara as it pushed southward. If the massive flow of refugees across the border continues, it will only

Ecological Dominoes

For the 75,000 members of the Kababish tribe of northwestern Sudan, ecological decline is painfully immediate. Dying baobab trees, the disappearance of once-plentiful grasses that sustained camels, goats, and sheep, and an unaccustomed scarcity of wild leopards, hyenas, and oryx all signal the twilight of a way of life. Like hundreds of other nomadic tribes across Africa, the Kababish have been forced to sell their emaciated livestock at a loss. While waiting for rain, their families survive on relief grain or head for distant cities where rumored jobs often fail to materialize.

From the Sudan west to Senegal, across the belt of savannas known as the Sahel, ecological dominoes are starting to fall. As grazing and wood gathering increase in semiarid grasslands, rapidly reproducing annual grasses replace perennial grasses and woody shrubs such as acacia and mesquite. The loss of the native acacias means less forage for cattle during the annual dry season, when the protein-rich acacia pods are used for feed. Drought years pose unusual hardship once annual grasses dominate the landscape. Unlike many perennials that are able to draw on nutrients and moisture stored in their roots, the annuals may not germinate at all when the rains fail.

The changing mix of Africa's livestock reflects these basic ecological shifts. From 1950 to 1970, herds of cattle expanded faster than flocks of sheep and goats. But since 1970, drought has killed off many of the grasses cattle find most nutritious. Cattle herds have grown slowly or declined, while sheep and goats are more numerous. Herded by children, sheep and goats scavenge the remaining woody shrubs and push the land further toward instability.

The disruption of this livestock-based society has troubling implications for all peoples whose lives depend on the integrity of the land. According to British teacher Michael Asher, who has lived among them, the future that faces the Kababish "may not merely involve the humiliation of settlement, but the disaster of extinction." *E.C.W.*

be a matter of years until there are more Mauritanians in Senegal than in Mauritania.

Gojam Province, northwest of Addis Ababa, illustrates a future that is all too likely for many of Africa's children. According to the World Bank, "By the turn of the century, Gojam will have no trees, no surplus dung, and merely old tree roots, brush and grass for fuel. This situation will be mirrored in Hararghe, Bale, and so on across the middle belt of highland provinces, all reaching more or less the situation of Eritrea today within ten to twenty years."

Tree cover is declining in eleven West African countries. From Mauritania's acacia savannas and Rwanda's mountain forests, peasant women and their children gather ten times more wood for fuel than the forests produce in new growth each year. In the woodlands of Kenya, Ethiopia, Tanzania, Nigeria, and Sudan, the sustainable yield supplies only half the fuel actually collected.

Until about 1965, Sudanese families gathered less wood than their forests produced each year in new growth. As families expanded, however, demand exceeded the annual growth and began to reduce the forest itself. By the early 1980s, the country's stock of trees had shrunk by a fifth. As the forest retreated, needs for wood escalated.

At its current rate, Sudan's population doubles every twenty-four years; the imbalance between wood supply and fuel demands is thus certain to widen in the next two decades. Only the most extraordinary efforts in family planning and tree planting will prevent the exhaustion of the remaining woodlands.

Many of Sudan's ten million children spend their days gathering the shrubs and twigs needed for family hearths, where more often than not, relief grain sent from a distant continent simmers in the cooking pot. The country's fields already produce less food per acre than they did a generation ago, and despite the clearing of new land, each Sudanese child has less food at the end of the harvest than his or her parents did. The next generation of youngsters, born by the end of this century, may not even recognize the trees that sheltered their grandparents just a few decades before.

Edward C. Wolf

As drivers in Japan and the United States tank up on the cheaper gasoline

that has recently become available, we can easily forget that almost 2 billion people will not benefit from recent oil price reductions. Rural villagers—almost half the world's population—were long ago priced out of the oil market, and even $15 per barrel of oil will not bring them back. For the children of these billions, as for their parents, life continues to include a daily struggle to gather enough wood, crop residue, or animal dung to cook the day's meals. In most countries it is women and children who are the main fuel gatherers.

Industrial countries have largely made a successful adjustment to an era of higher oil prices. Between 1979 and 1984, oil consumption declined 18 percent in Western Europe, 16 percent in North America, and 16 percent in Japan. Oil consumption per unit of gross national product—a good measure of oil dependence—fell 36 percent in the Western industrial countries and Japan between 1973 and 1984.

Most of this reduction comes from major improvements in energy efficiency—everything from

weatherizing homes to more efficient automobiles. Starting with very high levels of oil consumption, industrial nations had a lot of fat they could squeeze out of their energy systems and enough capital to pay billions of dollars for energy efficiency improvements.

But making investments takes money. In most developing countries, oil imports have continued to rise. The happy exceptions include Brazil, whose successful alcohol-fuels program now provides half the country's automotive fuel; Colombia, which is fast becoming a major oil and coal producer; and the Philippines, which is using everything from geothermal energy to coconut shell combustion to reduce reliance on imported oil. But most Third World countries are short of domestic energy resources and of the capital needed to develop them. Many African nations have curbed oil imports because they simply cannot afford to pay for them.

Just as industrial countries claim the lion's share of the world's energy, so within developing countries, wealthy city dwellers get priority over those who live in rural villages or urban shantytowns. High-priced cars running on foreign oil speed past small huts whose owners cannot afford enough charcoal to cook two meals a day. Most government investment goes to large generating plants and high-tension powerlines that serve modern industries and hotels and bypass thousands of unlighted villages.

Cooking is undoubtedly the most basic and universal activity that requires energy. Even in tropical countries where people can live fairly comfortably without heating, a small amount of energy is necessary to cook meals. In rural areas of the Third World, whether it be Africa, Asia, or Latin America, virtually all cooking is done with wood, crop residues, or animal wastes.

The use of these organic fuels for energy has increased an estimated 24 percent between 1970 and 1981. As populations expand and forests continue to dwindle throughout most of the developing world, biofuels have become steadily less available. The United Nations Food and Agriculture Organization estimates that one billion Third World people now suffer a fuel deficit. A mother of four in Africa may spend up to 2,400 hours each year collecting fuelwood (almost half of her waking hours), twice as much time as was required a generation ago. Where fuelwood and charcoal are sold, the price has risen. In much of the Third World the "energy crisis" continues, and the "oil glut" is a meaningless abstraction.

Many efforts to meet the energy needs of rural villagers have been undertaken, with mixed results. Village forestry projects, almost unheard of a de-

Hisham Fahed Yousef Al-Ghanim, age 7, Kuwait

U.S. Committee for UNICEF

cade ago, are now found in scores of countries. Most international aid agencies now include community forestry among their major assistance programs, and developing countries themselves are devoting more attention to this problem. It is nonetheless estimated that worldwide reforestation programs would have to be expanded fivefold in order to halt deforestation. In Africa the figure is fifteenfold.

Among the new reforestation programs, there are almost as many failures as successes. Problems often arise because local people are not consulted in the design of the program or have no stake in its successful outcome. Because villagers often derive fodder and building materials, as well as fuel, from trees, careful selection of species is essential. In the Philippines, World Bank-supported forest plantations have been burned because local herdsmen not involved in the program continued to set fire to nearby pastures. And some fuelwood projects are so expensive that local people cannot afford to purchase the harvested wood.

There are some notable success stories as well. In Haiti, an agroforestry project has used existing local networks of nongovernmental organizations to promote tree planting. Farmers are provided with inexpensive seedlings and technical advice and are free to reap the income generated when the wood is converted to charcoal and sold. More than 10 million seedlings have been planted by thousands of village families over a period of three years. In Gujarat State in India, where tree nurseries are tended by schoolchildren and individual farmers, more than 200 million seedlings are now distributed each year; roughly 600 square miles have been planted.

Major efforts have also been made to improve the efficiency with which fuelwood and crop residues are burned. At least 100 programs to introduce improved cookstoves have been started, again with mixed results. Many introduced stoves have turned out to be expensive, cumbersome to use, or just marginally more efficient. Because people often like to see an open fire and because the smoke in a dwelling keeps away unwanted insects, many people have gone back to the traditional three-stone fire.

Efficient cookstoves are no cure-all for Third World deforestation. On the other hand, properly designed stove programs have helped reduce the time needed to gather fuels and have improved living standards in many villages. A clay-and-sand stove developed in Senegal is now being built by village women. About 3,500 stoves were completed in two years, and a later survey found that 77 percent were still in use. In China the government says that 18 million improved cookstoves have been introduced. And in several countries, simple bread-box-style solar cookers have been developed and are being successfully used on a limited scale.

The energy situation of rural villages is far more complex than once imagined, and patterns of use vary widely even within a single country. People in a moist, heavily forested area might rely entirely on wood for fuel, while those in a rich, agricultural area burn crop residues, and those in an arid, deforested area have little fuel of any kind. Development specialists with narrow focuses often miss the mark. For example, many "high-yielding" rice varieties have short stems and so have a low fuel yield. Their introduction could be devastating in areas heavily dependent on the burning of rice straw.

The Third World will undoubtedly continue to be energy-poor for generations to come. But energy shortages do not necessarily mean poverty. Continuing efforts to develop new technologies matched to local needs and resources can greatly raise village living standards in the years ahead. When the inevitable future oil crises strike, the industrial countries with their still substantial oil dependence may well be the most vulnerable.

Christopher Flavin

Cooking with Biogas

China has taken a unique approach to meeting the fuel needs of rural villagers. In addition to its notable forestry and cookstove programs, China has built millions of household "digesters," which convert animal and human wastes, as well as crop residues, into biogas—a gaseous mixture, composed largely of methane, that makes an excellent cooking and lighting fuel.

In much of China, even in relatively prosperous areas, local forests were long ago cut down to make farmland, and so more than half of rural cooking is done with crop residues, 60 to 80 percent of which are estimated to be burned as fuel. China's biogas program began in the early 1970s, and by 1978 a crash effort had resulted in the installation of 7 million digesters, mainly in Sichuan Province in southern China. Unfortunately, as with many crash efforts, this one had problems. Designs and materials were often faulty, and many digesters leaked. Only about one-third of the original systems are now in use.

In the early 1980s, China restarted its biogas program, this time relying more heavily on village initiative and county extension programs, which provide technical advice. Local people build and maintain the digesters, which are usually located next to each home in the village. About 4.5 million of the devices are now in use; each can provide enough gas to cook three meals a day during most of the year.

China's biogas program illustrates the many benefits of a well-designed village fuel effort. Biogas systems have helped to improve sanitation and reduce disease in some villages. In addition, the residue from the digesters is an excellent fertilizer and has boosted agricultural yields. The residue has also proved an excellent feed for fish that are raised in local ponds and often sold for a handsome profit. *C.F.*

Larysa Turner, grade 5, United States

Studio in a School

The electricity industry has begun to reverse its trend toward centralization,

which started 104 years ago when Thomas Edison switched on the world's first power plant in Manhattan. Edison's great grandchildren may well live to see the formation of a dramatically more efficient and decentralized electric power system.

Since the end of World War II, the world's electric power systems have been dominated by large utility monopolies and by ever larger power plants—fueled chiefly by fossil fuels, hydropower, and nuclear energy. Pioneered in the United States but soon mimicked from Brazil to the Soviet Union, the central power approach was for decades considered a huge success. By the 1970s, almost two-thirds of the world's people had some electricity, and as prices fell, many people steadily expanded their use of electrical appliances.

But since 1973, higher fuel prices and cost overruns on nuclear power projects have raised the price of electricity in much of the world, bankrupting some industries and causing problems for many low-income consumers. In France, the state utility has built up a nuclear power-related debt of $30 billion that will be paid by generations of French men and women. In the Philippines, even city dwellers cook with charcoal because they cannot afford electricity.

Coal, currently the largest source of electricity worldwide, is polluting the air and causing acid rain, which presents a long-term threat to forests and fisheries. Although it was once assumed that a generation hence nuclear power would have replaced coal, there is now a de facto nuclear moratorium in many countries, including the United States. The cost and financial risk of nuclear power have done more to damage its prospects than have protesters. Even France, which is firmly committed to nuclear power, is now starting just one plant each year. Unless there is an unexpected turn of events, nuclear power will have leveled off, providing about 20 percent of the world's electricity at the turn of the century.

The problems associated with coal and nuclear power have spurred efforts to find alternatives that will spare the global environment, stretch out remaining fossil fuels, and hold down electricity prices. The cornerstones of the new strategies are major improvements in efficiency and development of small-scale generating technologies, many using renewable energy sources.

The average efficiency of new household appliances in the United States has already risen 20 to 30 percent in the past five years, and in Japan it has increased by 50 percent. Socket-type fluorescent light bulbs are now available that use one-quarter

Kenyetta Wilson, grade 7, United States

Studio in a School

as much electricity as conventional bulbs. Although they are expensive, they repay their cost three times over. New industrial motors are 30 to 50 percent more efficient. As a result, annual growth in electricity consumption in the United States has fallen from 7 percent a decade ago to 2 percent annually in recent years.

The efficiency potential has only begun to be tapped, however. Modern technologies can now save electricity at less than half the cost of producing it at even the least expensive new power plant. Some of the most efficient technologies are languishing in laboratories or on retail shelves, ignored by consumers who, protected by government subsidies from the full brunt of electricity price increases, are reluctant to pay a slightly higher price for a more efficient appliance.

Until recently the cliché that a penny saved is a penny earned has been a foreign concept to most utility planners. One way of eliciting efficiency from providers, however, is to treat improved electrical efficiency as if it were a new power plant and to give the utility itself some of the responsibility for—and financial rewards of—building that plant.

Austin, Texas, for example, is "building" a municipal "conservation power plant," a project that provides 553 megawatts by lowering demand instead of increasing supply. The city-owned utility advances consumers the cash for any household and commercial-efficiency improvements deemed cost effective, such as weatherization or the replacement of energy-guzzling appliances. This immediately reduces the customer's demand for electricity. The customers are charged for the investment via their usual electric bills over several years, but because power needs are reduced, they pay less in total than they would have before the improvement was made. Everyone benefits because the utility has avoided building a coal-fired plant that would have cost $600 million more than the conservation efforts.

Several studies show that such a program writ large could reduce growth in electricity consumption in the United States and most other industrial countries to near zero, while electricity itself becomes a more productive power source. Improved efficiency is not a free lunch, but it is the closest thing to it in the electricity business today.

Engineering dogma has long held that power plants must be large in order to be efficient and economical. That argument, first punctured by the

California's Electricity Revolution

Fundamental changes in the electricity industry first took hold in California in the late 1970s. After protracted political battles, California's consumers and the government under Gov. Jerry Brown gradually pushed the state's utilities in a new direction.

The centerpiece is efficiency: California utilities that once were penalized by state regulators for inefficiency have made investments that are projected to save between 12,400 and 19,600 megawatts of peak power demand by 1996, savings that will be worth $2 billion per year in terms of power plants that will not have to be built.

The surge in independent power generation has also been remarkable. By mid-1985, the state's independents had 1,921 megawatts connected to utility lines—equivalent to two nuclear plants—and had signed contracts for another 12,995 megawatts, enough to meet 39 percent of the state's peak power needs. The California Energy Commission sums up the changes as "the final stages of a transition from an era of scarcity to an era of abundance."

A generation from now, California's per capita electricity consumption will have fallen by at least 20 percent, and yet the productive role of electricity in California's economy will actually be greater. And California may soon have an extraordinarily diverse electricity system: cogeneration is likely to provide more energy than will nuclear power, while wind power may well surpass oil. With at least eight major sources of electricity, California's power system will be much more resilient than it is today. *C.F.*

cost overruns on some of the largest nuclear plants, has been destroyed by the economical completion of many small power plants in the United States in recent years. Small plants are naturally more suited to mass production and standardization than are large plants that must be custom designed for a particular site. These smaller technologies have been commercialized only since 1980, but as industry has geared up to produce the new power sources, costs have been rapidly brought down and reliability improved.

In New England and the Northwest, wood-fired power plants are being built for $1,500 to $2,000 per kilowatt, competitive with the cost of some coal-fired plants that are ten times as large. Cogeneration—the combined production of heat and power, usually using natural gas—is being employed by businesses ranging from huge oil refineries to fast-food restaurants; and again the cost comes in under that of new coal-fired generation.

The new power sources are booming. Figures from the U.S. Federal Energy Regulatory Commission show that more than 1,000 such projects, with a generating capacity of 30,000 megawatts—equivalent to thirty large nuclear plants—have been registered since 1980. At the pace established since 1984, the independent power industry could provide enough capacity nationwide to meet a 1 percent annual growth in power requirements. And tapping the efficiency potential should lower demand growth to less than that rate.

These small power projects are being developed not by utilities but by independent companies that sell their power to the large established firms, a transaction that was made possible by the Public Utility Regulatory Policies Act passed by the U.S. Congress in 1978. For the first time in over a half century, the utility monopoly has been broken, and electricity is becoming a competitive business. Unlike large, regulated utilities that have little incentive to improve technologies and aggressively push costs down, small power producers have much to gain. In five years, this infant industry has grown to a $5 to $10 billion a year business in the United States. It is being closely studied by electricity planners in several countries.

What sort of an electricity system can our grandchildren look forward to? For one thing it may be a good deal less polluting than the current system. In the United States, for example, coal use may be kept at about the current level rather than doubling or tripling consumption. With the advent of cleaner coal-burning technologies, sulfur dioxide and other noxious air pollutants can be greatly reduced. Improved efficiency and new generating technologies should also put a cap on electricity prices, which have spiraled upward throughout the past decade.

The electricity delivery system is likely to

Raysa Abreu, grade 4, United States — Studio in a School

change gradually over time so that rather than receiving power mainly from one or two distant coal or nuclear plants, a consumer might be served by a diverse array of local cogenerators—say a hospital or department store—as well as a wind farm, a small hydropower project, or a municipal waste-fired power plant. The electricity bill would still be sent by a single utility company, but that company would channel much of the fee to the small power producers that are actually generating the electricity.

Eventually a more drastic change will probably take place: many consumers will themselves become electricity producers, using solar cells on the rooftop and natural-gas-driven fuel cells in the basement, which will also provide domestic heat and air conditioning. The local neighborhood would become an electronic bazaar with a constant buying and selling of electricity, all monitored and controlled by a microelectronic chip. Some "consumers" might receive checks rather than bills at the end of the month.

Christopher Flavin

Lanky teen-agers on the streets of Tokyo, who can literally look down on

their parents, provide visible evidence of the link between food supplies and physical development. So too do the emaciated faces of African children that stare at us from our television screens. These extreme examples represent the diverging trends that are shaping the bodies and minds of the next generation.

A generation ago, Europe and Asia were still recovering from the devastation of World War II. During the years immediately following World War II, Europe was supported by food relief from the United States. So too were many Asian countries. As recently as the mid-1950s, the average Japanese diet, long on starch and short on protein, was scarcely above the subsistence level.

During the decades since World War II's end, changes in the world food economy have been

Ahmad Hossen Zadeh Faridon Majli, age 12, Iran

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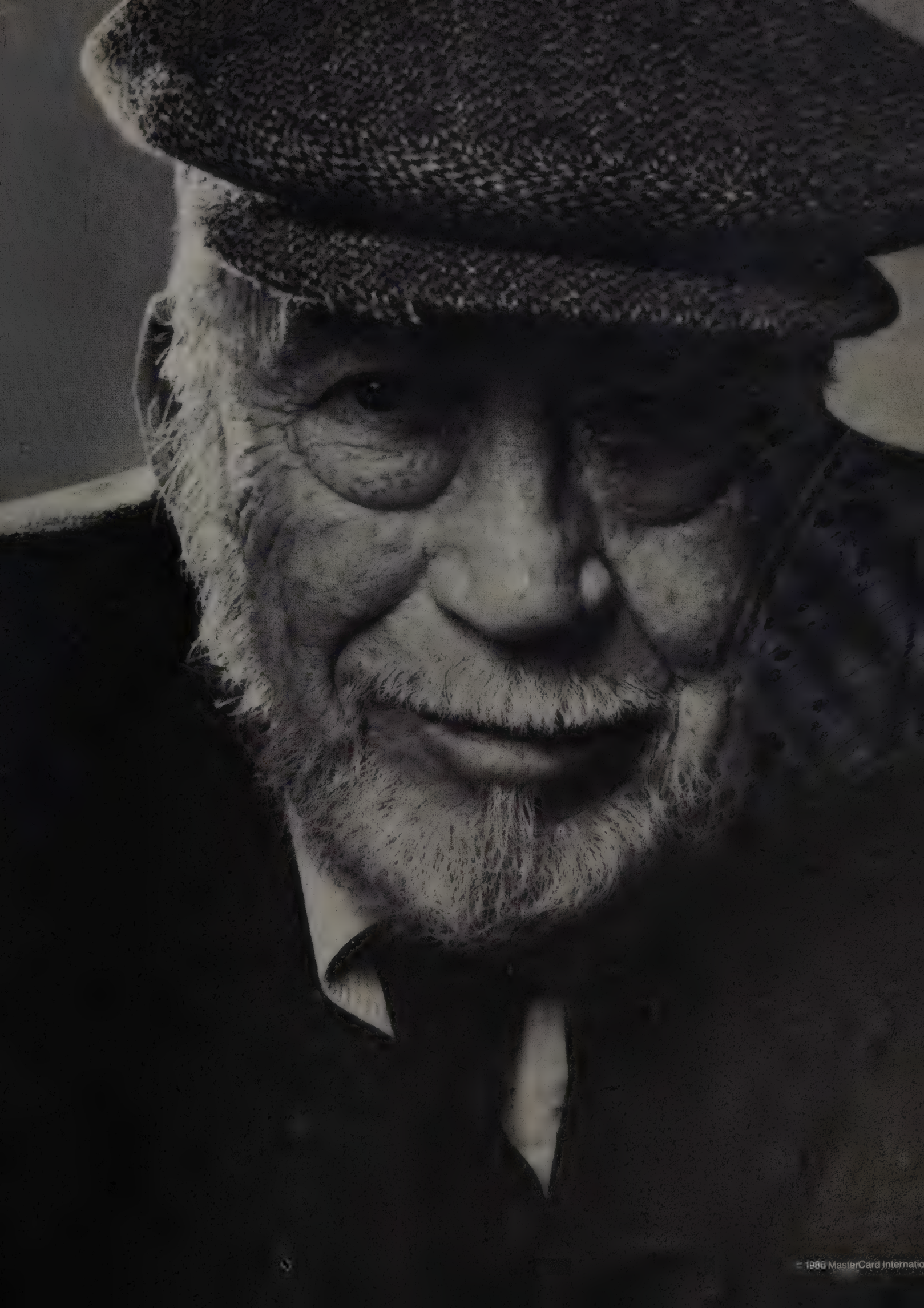
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dramatic. A nation's ability to produce or import grain—which supplies half of the world's food calories when consumed directly and part of the remainder when consumed indirectly, in the form of grain-fed animal products, such as meat, milk, butter, and eggs—is a useful indicator of the dietary status of its people. More than forty Third World countries are now producing less grain per person in the mid-1980s than they did in the early 1950s. The declines range widely, from 85 percent in Lebanon to 2 percent or less in Bangladesh and Costa Rica. The great majority of the countries are in Africa, the Middle East, Central America, and the Andean region—areas where ecological deterioration is proceeding most rapidly.

Satisfying the bare minimum of calories and protein requires approximately 400 pounds of grain per person per year, or slightly more than one pound per day. And while this is enough to keep body and soul together, it will not sustain a high level of physical activity.

When cereal consumption drops below the minimum requirement of grain (or its equivalent in other starchy staples, such as potatoes or cassava), countries face the severe malnutrition and famine now afflicting so many African countries. Countries that produce less than 400 pounds per person must either import grain or watch their people go hungry. At the upper end of the range, grain use is bounded only by the human capacity to consume livestock products, as in the United States and Canada, where grain consumption reaches roughly 1,750 pounds per person per year.

Those at either end of the grain consumption ladder may suffer from the effects of an unhealthy diet. Too few calories cause underweight and malnutrition, while too many fat-rich livestock products contribute to heart disease and certain cancers. At the low end of the consumption scale, the most likely victims are children and pregnant and lactating women. In societies where grain consumption is excessive, they are more likely to be middle-aged adults.

When food supplies are short, children suffer the most. Adults need only enough food to maintain metabolic processes, whereas children need food for growth as well. Severe food shortages during early childhood, such as those experienced in many African countries in 1984 and 1985, stunt the development of both bodies and minds.

The worldwide relationship between human numbers and food production is uneven. A few countries, such as the United States, Canada, Australia, Argentina, and France, produce far more than they consume. Most of the rest of the world, however, imports grain. Indeed, in 1985 more than 100 countries imported grain from the United States alone.

Among the world's regions, North America stands out as the major surplus producer. Over the past generation, its grain exports have increased nearly fivefold, firmly establishing it as the world's breadbasket. More recently, other geographical regions have undergone sudden shifts. As recently as 1970, for example, Western Europe was a heavy importer of grain, while Africa was essentially self-sufficient, though at a meager subsistence level. Since then, surging grain production in Western Europe, spurred by high, guaranteed farm prices, has increased harvests by nearly one half. With population growth at a near standstill, and diets almost saturated with livestock products, expanding output has shifted Western Europe to the surplus side of the world grain ledger. Now Western Europe exports almost as much grain as Australia, ending a dependence on grain imports that began with the Industrial Revolution.

Unknown, R.K. Centrale School, Netherlands U.S. Committee for UNICEF

Africa, meanwhile, has gone the other way, importing some 29 million tons in 1985. With each ton sustaining nearly six people, some 170 million of the continent's 550 million people were kept alive in 1985 with imported grain. Africa's swelling grain deficit stems from the failure of its agricultural and population policies. Declining per capita food production for the continent since 1967 has created deficits in Africa that are now the rule, not the exception.

While Western Europe has been achieving broad-based gains on the food front, the Soviet Union and Eastern Europe have been backsliding. Since 1978, Soviet grain production has fallen in

Melanie Cunningham, grade 4, United States — Studio in a School

absolute terms, marking the first time in recent history that a major food-producing country has experienced a sustained production decline. Such a drop is difficult to explain in agronomic terms alone, suggesting that low morale among agricultural workers may be affecting productivity. As a result of this downturn in production at a time when Soviet leaders are attempting to raise the consumption of livestock products, the Soviet Union now imports more grain than the entire continent of Africa.

Grain production is also falling off in Latin America. The production peak in this region came in 1982, the year the debt crisis surfaced. In Brazil and Mexico, for instance, reluctance to use foreign exchange to import fertilizer and other agricultural aids played a role in the downturn. So too has the overall weakening of demand associated with the fall in income caused by the fiscal belt-tightening in so many debt-ridden Latin American countries. In effect, the foreign exchange deficits of the past, which are depressing economic output and incomes, are contributing to the nutritional deficits of the future.

For the Indian subcontinent, home to nearly one-fifth of humanity, agricultural trends have been mixed. India's production of grain, with impressive increases in yield per acre, has increased enough to eliminate imports, but not enough to eliminate pervasive malnutrition. Consumption of leguminous crops such as chickpeas, which are a key source of protein in the largely vegetarian Indian diet, has fallen by one third during this period.

The major bright spot in the world food economy over the last decade has been China. With more than one-fifth of the world's people, it has achieved cereal self-sufficiency, dramatically raised per capita food consumption, and largely eliminated malnutrition. A combination of advances in food production and health care give children born in China in 1986 a life expectancy approaching that of children born in the United States.

In response to the shifting balances between food demand and supply, the world's grain-trade pattern has shifted. At midcentury, most of the grain that crossed national borders flowed across the Atlantic, from North America to Western Europe. Today, most grain shipments between continents cross the Pacific, from North America to Asia, now the world's leading importer.

Twenty years ago Asia's grain imports were mostly food grains, principally wheat going to India and China. Today they are predominantly feed grains imported by Japan, South Korea, and Taiwan to support their burgeoning poultry and livestock industries.

After a generation of efforts to eliminate hunger,

Central Africa: Cassava Versus Corn

For centuries, farmers in the central African highlands of Rwanda, Burundi, and Zaire planted a mix of crops—millet, sorghum, peas, groundnuts, and yams—on the wooded savannas that lie east of the Congo–Nile divide. In the early 1900s, newer crops for consumption (corn, beans, potatoes) and for export (coffee) were introduced. Coffee, grown in small amounts, supplemented subsistence life styles by providing farmers with some cash to buy things they could not otherwise obtain.

Since 1900 the population of the central highlands has quadrupled to 12 million people—primarily as a result of better health care. Now this region is one of the most densely populated in Africa. Because 90 percent of the inhabitants are farmers, new land for cultivation is increasingly scarce. As the number of people grows and farm plots are subdivided to accommodate new households, farmers are changing their practices in ways that deplete the soil and gradually erode their families' nutritional standards.

Many farmers attempt to feed growing families on small plots of land by replacing corn and other high-protein grains with tubers, such as sweet potatoes and cassava. This kind of substitution maintains a family's diet purely in terms of food energy, since tubers yield more calories per acre than grain. Nutritionally, however, the trade-off is a loss, since tubers have almost no protein.

The effort to grow more food also means that many fields in the highlands are now continuously cultivated. Without fallow periods, the soil is depleted of minerals and its fertility declines. A crucial turning point is reached when tubers begin to crowd out the leguminous bean crops that not only supply high-quality food protein but also add nitrogen to the topsoil.

Because population continues growing even after all available farmland has been cultivated, families that once sold their surplus crops for cash return to a purely subsistence life style, relying more heavily on land to produce food for immediate household needs.

Unless this downward spiral is reversed, chronic malnutrition rather than fertile land may be the unintended birthright of future generations in the highlands. Each additional child born represents an inheritance tax on brothers and sisters, as already small plots are divided and redivided, and as nutritional quality is sacrificed to feed growing numbers of people.

Jodi L. Jacobson

results are mixed. Hunger and malnutrition are commonplace in Africa, Central America, the Andean countries, northeastern Brazil, and the Indian subcontinent. The big gain has been East Asia, where over a billion people who live in countries where diets were inadequate a generation ago are now well nourished. Whether the next generation will bring similar advances in countries still plagued with food shortages depends heavily on efforts to slow population growth.

Lester R. Brown

Both Phoenix, Arizona, and the African town of Lodwar, Kenya, average seven inches of rainfall each year. At the touch of a tap, the child of a family in the American Southwest has an abundant supply of clean water for drinking, bathing, and swimming in a backyard pool. Such a family's water use may approach 1,000 gallons per day. A child in eastern Africa, on the other hand, may accompany its mother on a daily trek to a well and help her carry back six gallons of water for the entire household, barely enough to sustain life.

In Phoenix, powerful pumps lift water from hundreds of feet underground. In late 1985, the city celebrated the arrival of Colorado River water via a 190-mile-long canal—a lifeline for economic growth. But the benefits from such development of water resources are neither secure, long-lasting, nor universally shared.

Many of the world's farms and cities thrive by using water at an unsustainable rate. Depletion of aquifers—the water-bearing layers of sand or rock that lie beneath the earth—falling water tables, and diminished streamflows signal that some of today's demands are being met by drawing down and degrading future supplies. In the United States, of the 88 billion gallons of ground water pumped each day, 18 billion—one-fifth—are nonrenewable. Using this water depletes reserves and supports only a fragile and short-term prosperity at best. Eventually the water becomes too salty to use, too expensive to pump to the surface, or runs out altogether.

Beneath a quarter of the irrigated cropland in the United States, underground water levels are dropping from six inches to six feet per year. In spite of diminishing supplies, Sunbelt cities continue to burgeon. Tucson, Arizona, expected to triple its population by the year 2025, now meets half of its present water demand by mining its aquifers. Water tables in portions of the city have dropped more than 150 feet. In sections of the Dallas-Fort Worth area, water tables have fallen more than 360 feet during the last twenty-five years. El Paso, Texas, one of the fastest-growing cities in the nation, now gets most of its fresh water from an aquifer that geologists predict will be depleted in thirty to sixty years.

Although rarely as well documented as cases in the United States, overpumping of ground water appears widespread. In areas of Tamil Nadu in southern India, water tables dropped seventy-five to ninety feet during the 1970s: a result of uncontrolled withdrawals for irrigation. Overpumping is also epidemic in China's northern provinces, where ten major cities rely heavily on ground water for their basic supplies. In portions of Tianjin, a major manufacturing city, water levels are falling fourteen feet annually. A recent assessment of the water situation in Beijing—home to more than 9.2 million people—concludes that "unless remedial measures are taken immediately and implemented on a sustained basis, sooner or later the city will run out of water."

Natural lakes and streams are also being severely damaged by excessive water use. In Soviet central Asia, withdrawals for irrigation have so reduced freshwater flows to the Aral Sea that the sea's surface area has shrunk nearly 30 percent since 1960. Fisheries once important to the region's economy have virtually disappeared. Similarly, the diversion of California's rivers and streams to sup-

John Corso, grade 4, United States — Studio in a School

ply growing cities in the state's drier south has completely desiccated one lake and reduced another's surface area by a third. Biologists recommend that in the western United States no more than 40 percent of a stream's average annual flow should be depleted. But in many river basins, depletions already total between 60 and 80 percent of streamflow. The ecological consequences are incalculable, and in some cases probably irreversible.

Forests and grasslands absorb rainwater, allowing it to percolate through the soil and move slowly through the subsurface. This underground water then feeds rivers and streams during the dry season. In many Third World countries, however, the denuding of hillsides through deforestation and overgrazing has caused the rapid runoff of rain and soil in floods and the disappearance of streams during the dry season. On the small Caribbean island of Dominica, forest clearing has contributed to a halving of dry-weather streamflow. Although impossible to quantify, deforestation—now estimated at 28 million acres per year—could be shrinking the Third World's stable water supply by as much as costly new dams and reservoirs are augmenting it.

Perhaps most alarming of all, populations continue to grow fastest in some of the world's most water-scarce regions. By the year 2000, Kenya's population may nearly double, so each person will then have only half of today's per capita water supply, assuming rainfall stays at its historical level. In Bangladesh, supplies per person may fall by a third, and in India by a fourth. Indeed, projections by leading hydrologists show that in the year 2000, meeting water demands in North Africa and the Middle East will require virtually all the usable freshwater supplies in these regions. Demands in central and southern Asia will also be uncomfortably close to the volume of water these regions can safely and reliably tap.

Against this sobering backdrop, meeting the food and material needs of the next generation presents a sizable challenge. Until now the spread of irrigation has helped food production to keep pace with or exceed population growth in most regions (Africa is an important exception). But

Suhailah Abdulla Turab, age 10, Oman

US. Committee for UNICEF

Underground Reservoirs

In many parts of the world, water is being pumped out of the earth faster than rainfall can replenish it. The result—falling water tables and shrinking water reserves—tells us that we are borrowing water from the next generation. Artificially recharging underground supplies is one promising way to stabilize water tables, to secure a reliable supply for dry spells, and to save for the future.

More than twenty countries now augment natural recharge, either by spreading water over land (where it then percolates to an aquifer below) or by injecting water into the subsurface through a well. Israel is among the few countries that have adopted this practice on a large scale. The nation transfers—through canals and conduits—80 billion gallons of water from north to south every year and stores two-thirds of it underground. There it is saved to meet the peak demands of summer and to provide a reliable backup supply for especially dry years.

In China, several counties in Hebei Province are artificially recharging ground water to combat sinking water tables. Engineers in Beijing, a city of chronic water shortages, have drawn up plans for the underground storage of more than 200 billion gallons of water, which would be captured during wet seasons. They estimate the cost to be one-third that of a surface reservoir of similar capacity.

Underground storage may hold special potential for Third World countries subjected to the destructive flooding and perennial dry spells of a monsoon climate. Capturing runoff and storing it underground can convert damaging flood waters into a stable resource, while avoiding the large evaporation losses of surface reservoirs. In India, subsurface storage has sparked interest as a way of reliably irrigating the productive soils of the Gangetic Plain. According to some estimates, a fully irrigated plain could grow enough crops for 600 million people—60 percent of India's projected population in the year 2000.

Although not a substitute for conservation and greater water efficiency, the recharging of underground supplies offers some promising prospects. As Soviet hydrologist M.I. L'vovich has written, "The twenty-first century will undoubtedly be the century of underground reservoirs." *S.P.*

large new irrigation projects in most of the Third World now cost an average of $2,000 per acre, and in Africa, the needed investment is often two to three times higher. Since such costs far exceed the expected returns from harvesting food crops, large-scale irrigation may not help feed the still-to-come children of Bangladesh, Kenya, and Ethiopia.

Conservation and efficiency must lie at the heart of strategies for meeting future water needs. Increasing water efficiency by only 10 percent in the Indus region of Pakistan, for example, could provide enough water to irrigate an additional 5 million acres. On rain-fed lands, building small rain-collecting basins called catchments can secure more water for crops than they would otherwise get from rainfall alone. Experiments in Israel's Negev Desert suggest that microcatchments (small basins around individual trees and plants) may cost only $4 to $16 per acre. Since they work especially well with tree crops, microcatchments could bolster reforestation efforts that combine production of food, fodder, and fuelwood—an urgent need in sub-Saharan Africa.

Household needs now take less than a tenth of the global water budget, while 70 percent is used to grow food. But cities will absorb many of the projected 1.3 billion additional people who will populate the earth by the year 2000. Especially in rapidly growing Third World cities, meeting basic water and sanitation needs—which millions of people still lack today—will entail an enormous effort. Few of these cities can afford the kinds of water-intensive systems used in the United States. Supplying the projected populations in most Latin American cities, for example, will require that residential water use remain almost at its present range: 20 to 40 gallons per person per day, compared with 112 gallons in the United States. Many cities may find that only by carefully treating and reusing their water supplies can they hope to meet their residents' basic needs. Mexico City, with a population expected to climb from 17 million to 30 million by the year 2000, plans to meet about 10 percent of its projected water needs with treated waste water, freeing high-quality supplies for drinking and other household needs.

For much of the world, water development has worked wonders, turning deserts into fertile fields and making water supplies appear virtually limitless. Yet many of its benefits will be short-lived, and they may never reach the poorest segment of humanity. The water security of the next generation hinges on this generation's ability to cast off the illusion of water abundance and prepare for the reality of coming scarcities.

Sandra Postel

What do you do with a worn-out nuclear reactor? More than eighty

nuclear reactors around the world will have shut down by the year 2000. Another 162 commercial units will reach their thirtieth year of operation in the following decade. Unless sound decisions are made now about how to decontaminate, dismantle, and dispose of these reactors (a process called decommissioning) and how to manage thousands of tons of toxic materials, children living in the twenty-six countries that use nuclear power will be harnessed with the technical and financial burden.

The first commercial reactors were built in the

Soviet Union, the United Kingdom, and the United States in the late 1950s. Since that time almost 350 power reactors have been built worldwide and half again as many are under construction. Radiation buildup and embrittlement of the pressure vessel that contains the nuclear reactor limits a reactor's useful life to several decades.

Because radioactive fission byproducts build up within the uranium-filled fuel rods that power a reactor, the rods must be replaced every three to four years. This spent fuel is classified as high-level nuclear waste (as are liquids used to reprocess unused uranium from the spent fuel—a method used in several countries outside the United States). High-level wastes must be kept out of the food chain and water supplies until they have decayed to harmless levels. The spent fuel from power reactors remains more toxic than the original uranium ore for about three million years.

The U.S. Environmental Protection Agency has ruled that high-level wastes must remain isolated from the biosphere for 10,000 years—longer than recorded history. But not a single repository now exists anywhere in the world that accepts commercial spent fuel. At present, each facility stores and cools its own wastes in on-site "holding ponds." The first high-level waste burial site in the United States will not begin operating until 1998 at the earliest.

Centralized, away-from-reactor storage is planned in Sweden and being debated in the United States. Spent fuel is extremely warm when removed from the reactor core and the longer it is stored above ground, the more radioisotopes decay and the cooler the mass becomes. Many experts think intermediate aboveground storage would make permanent geologic disposal safer, but critics fear this strategy is another tactic to postpone the start-up date of permanent repositories.

Low-level radioactive waste, a huge category that encompasses everything from work gloves and used equipment to contaminated water and soil, is much less toxic than spent fuel, but there is far more of it. Dismantling just one large reactor would yield 633,000 cubic feet of contaminated concrete and steel—enough to bury a football field under twelve feet of radioactive debris.

Since the 1983 London Dumping Convention instituted a moratorium on disposing low-level waste at sea, utilities and governments have had to decide whose backyard to put it in. The three low-level waste sites still operating in the United States almost closed their gates to shipments from outside their regions at the end of 1985, but last-minute legislative compromises have given slow-acting states more time to develop their own regional dumps. Local political opposition to proposed waste sites has been especially strong in Japan, the United Kingdom, the United States, and West Germany.

No one knows just how much it will cost to remove all the spent fuel in utility holding ponds, to

An Ignored Opportunity

In 1957 the first nuclear reactor designed to produce commercial electricity began operating twenty-five miles outside of Pittsburgh, Pennsylvania. The U.S. Department of Energy (DOE) built the plant to demonstrate that the same nuclear reactors used on submarines could power cities. A contract between the DOE and Duquesne Power and Light specified that Duquesne would lease the site to the government, operate the plant, and sell the electricity produced, and that the government would leave Duquesne with a clean site in 1994.

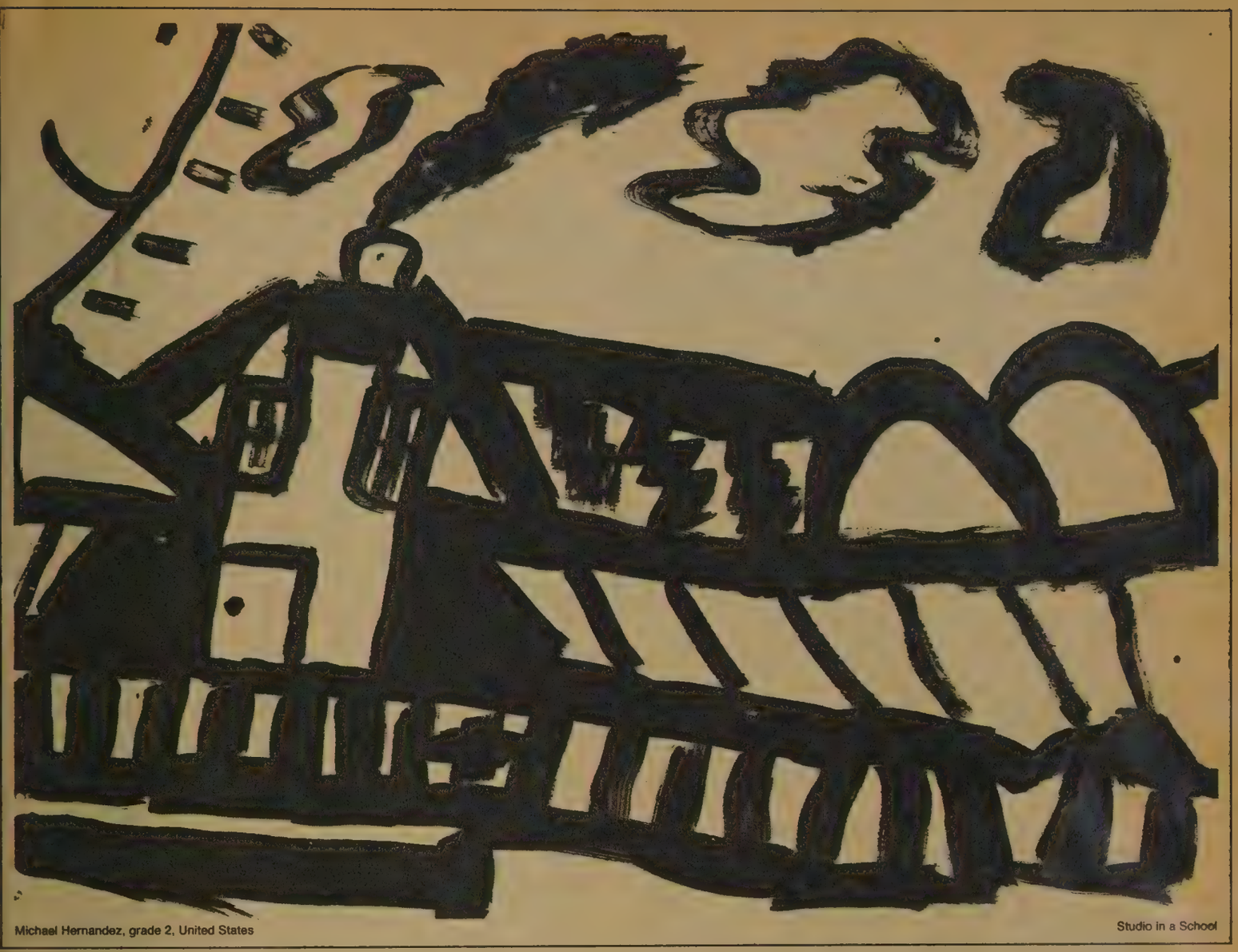
After twenty-five years of operation, the Shippingport reactor stopped generating electricity in 1982. The DOE's decommissioning plan was put into action. Because there are no commercial high-level waste facilities anywhere in the world, and because the reactor is owned by DOE, the spent fuel was transported by rail to the government-run Idaho National Engineering Laboratory.

The reactor itself will be shipped differently. The Department of Energy plans to encase the 33-foot-high steel reactor vessel in concrete, lift the 770-ton behemoth intact, and send it by barge down the Ohio and Mississippi rivers, through the Gulf of Mexico and the Panama Canal, and up the Pacific Coast and Columbia River. Sending the reactor by barge instead of truck is expected to cut $7 million, or 7 percent, off the total price tag.

Because Shippingport is being decommissioned in this way, it will not be of much value as a test case. Modern reactors, with ten times the generating capacity (though only about one-third larger), may be too big to ship in one piece. And not all power plants are located on major waterways. The dismantling of the pressure vessel and its contents—a step that will be skipped at Shippingport—will be the most difficult task facing decommissioning crews of the future. Tackling that problem now could provide valuable knowledge and experience.

Shippingport was built as an industry prototype, designed to interest electric utilities in nuclear power. Although it is tiny by today's standards, only 72 megawatts, the reactor will be the largest unit decommissioned to date anywhere in the world. By employing cost-cutting measures now, the Department of Energy is depriving the international nuclear industry, the same one it helped foster, of invaluable lessons. Saving millions of dollars today could cost the industry billions of dollars in the future.

Vital experience could be gained by shutting down a large reactor that is nearing retirement. As an international demonstration project, the primary owner could cover the bulk of the costs, with utilities, national energy agencies, and research institutes around the world chipping in the rest. The International Atomic Energy Agency in Vienna or the Nuclear Energy Agency in Paris would be the logical coordinating bodies. The damaged Three Mile Island unit has already set up a similar ad hoc financing arrangement so that interested parties can learn the latest techniques for decontamination and dismantlement. *C.P.*



Michael Hernandez, grade 2, United States

Studio in a School

decontaminate and dismantle complex reactor structures, and to dispose of all the high- and low-level waste. Estimates, based on limited practical experience, range from less than $100 million to several billion dollars per reactor. Unprecedented cost overruns during reactor construction do not bode well. Neither do the rapidly escalating costs of radioactive waste disposal, a large component of the decommissioning bill.

Making sure that enough money will be available for decommissioning is a task that utility executives, regulatory commissioners, and politicians have, for the most part, chosen to ignore. But unless money is set aside during the years the plant is operating, the bill would be charged to future customers who did not use the power, lead to solvency problems for utilities, or result in decommissioning shortcuts that could impair the health and well-being of future generations for thousands of years.

Electric utilities often argue that money collected for decommissioning should be placed in the companies' general revenues and used for all types of expenses, including the construction of more nuclear plants. This strategy allows utilities to forgo borrowing and keep debt payments low, but the method has been termed "phantom funding" by some observers because the money is invested in assets and is not readily available to the utility. In a study conducted for the U.S. Nuclear Regulatory Commission, University of Pennsylvania economist J.J. Siegel concluded that if an outside decommissioning fund were established, "it would be virtually impossible for the utility to divert these assets for other uses, and funds would be assured no matter what events, legal or financial, occur."

Of the four retired commercial reactors in the United States, decommissioning funds had only begun to be collected at one before it shut down. The Pacific Gas and Electric Company, owner of the Humboldt Bay reactor on the northern California coast, collected $500,000 during the plant's last four years of operation. This lack of financial planning in three instances, and the late and inadequate implementation in the fourth, has led eight states—California, Colorado, Maine, Massachusetts, Mississippi, New Hampshire, Pennsylvania, and Vermont—to require mandatory periodic deposits into external savings accounts.

In Sweden, each reactor operator pays an annual fee to the government. The funds are invested in separate accounts from which the utilities can borrow money to pay for decommissioning. Less for-

mal arrangements exist in West Germany and Switzerland.

Although few nations set aside money for decommissioning, funds for high-level waste disposal are collected in a dozen North American and European countries. In all cases, the money is paid to the government agency responsible for establishing geologic waste repositories. The fee typically ranges from one to three dollars per 1,000 kilowatt hours of nuclear electricity produced.

Regardless of nuclear power's role in a nation's energy plans, existing plants must eventually be scrapped. Since decommissioning bills will first fall due in those countries that pioneered the development of this energy source, their skill at managing the expense will be closely watched. Nations with newer reactors will learn valuable lessons, and countries that have not yet built such plants will be better able to judge the true lifetime costs of nuclear energy.

Cynthia Pollock

"Smoking will stunt your growth," parents have long warned their children.

Now we know that parents themselves stunt their children's growth by smoking. Parents who smoke cause premature delivery of, and low birth weight in, their infants. They cause respiratory disease in their children. They delay their children's physical and mental development and increase their offspring's risk of getting lung cancer.

And children who grow up in smoke learn to smoke. They imitate their parents, who, in the United States, are thirteen times more likely to die a smoking-related death than to succumb to hard drugs and eight times more likely to contract a fatal tobacco-related disease than to perish in an auto accident. American parents are not the only bad examples, for smoking has become a worldwide epidemic, increasing annually at 2.1 percent, outstripping world population growth.

More than 1 billion people now smoke, consuming almost 5 trillion cigarettes per year, an average of more than half a pack a day. Even in the United States, where the smoking portion of the population is declining, total tobacco sales have increased almost 20 percent, in part because those who do smoke are smoking more than ever.

Tobacco causes more death among adults than any other toxic material in the environment. It accounts for almost a fifth of all deaths in industrial countries, and over 2 million premature deaths worldwide each year. But these numbers do not count the health costs of children.

Children of smoking parents are involuntary smokers. If their mothers smoke, serious risk begins before birth. Babies of mothers who smoke during pregnancy weigh about one-tenth less at birth, and with this lower birth weight comes the increased risk that they will not survive.

Growing up in smoke makes children sick. Passive-smoking children have significantly higher rates of respiratory illness, including colds, influenza, bronchitis, asthma, and pneumonia, than the offspring of nonsmokers. One British study published almost ten years ago showed that children under age one whose mothers smoked more than one pack a day were twice as likely to get bronchitis and pneumonia. This finding has been repeatedly corroborated.

The evidence also indicates that parental smoking impairs physical development. One study found that lung capacity in teen-age boys was reduced by 7 percent by their mothers' smoking. If

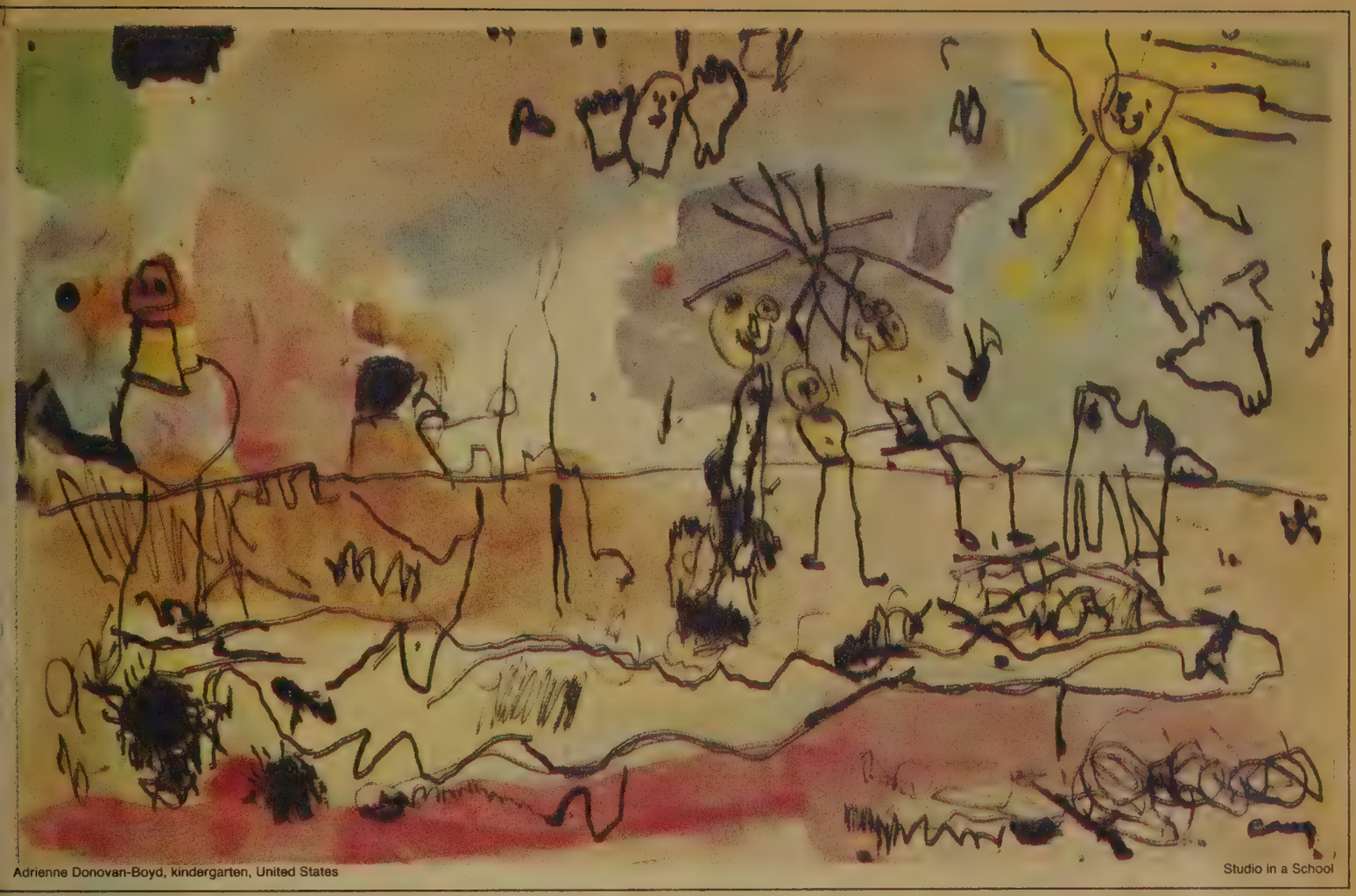
Smoking and the Unborn Child

Because birth weight is a key factor in infant mortality, tobacco use seriously endangers infants' lives. Researchers have found that the higher the levels of cigarette residue (thiocyanate) in infants' umbilical cords, the more likely a baby is to be born underweight. In one United States survey, smokers gave birth to underweight babies twice as often as other women did. In India where many women chew tobacco, low birth weight has also been associated with that habit. Nicotine, numerous toxic chemicals, and radioactive polonium may all interfere with fetal development, and the fetus can receive these substances through the mother's blood whether she smokes or chews tobacco.

Nicotine also may be the culprit in spontaneous abortions among women who smoke. Epidemiologist R.T. Ravenholt estimates that smoking causes 50,000 miscarriages in the United States each year. This connection has been observed in Italy as well, where women who smoke miscarry in the first month of pregnancy at a rate of 2.4 percent, compared with 0.9 percent for nonsmokers. Smoking is also strongly linked to premature delivery. Nineteen percent of the firstborn infants of Italian women who smoke were premature, twice the rate for nonsmokers. The rate of premature delivery in the Italian study declined by almost 25 percent for the secondborn children of nonsmokers, but it increased slightly for smokers.

Women in many countries are smoking in record numbers, even while pregnant. Surveys in the United Kingdom suggest that more than a third of pregnant women smoke. A compilation of surveys by Ravenholt showed that in nations as disparate as Sweden and Chile, more than 25 percent of pregnant women smoked. Each year, at least 3 million newborn children—the estimated number of live births to women who smoke—are thus potentially handicapped by their mothers.

W.U.C.



Adrienne Donovan-Boyd, kindergarten, United States

Studio in a School

the boys themselves smoked, their lung capacity was reduced by 25 percent. Intellectual development, too, may be imperiled. One study in Italy found that children whose mothers smoked learned to read more slowly than the children of nonsmokers. In the United States, the learning ability of a group of eleven-year-olds whose mothers smoked was shown to lag behind a control group by six months.

Unfortunately, passive smoking may end in death. Passive smokers breath the same carcinogens that cause lung cancer in smokers. Over a lifetime, the involuntary smoker is three times more likely to develop lung cancer than an unexposed peer.

Tobacco also afflicts children economically. Smoking-related illnesses, such as heart disease and lung cancer, often strike early, removing parents from their children while parents are in their prime. Additional thousands die as a result of fires caused by cigarettes and from cancers caused by tobacco consumed as snuff or chew.

Economic losses related to tobacco use are enormous, exceeding $100 billion yearly in the United States. Yet no country has taken action against tobacco commensurate with the cost it imposes. The global use of tobacco has grown nearly 75 percent over the past two decades. The Chinese have doubled cigarette use. Only four countries now use fewer cigarettes than in 1964. Greeks lead the world in per capita cigarette consumption. Japanese, Americans, Canadians, Yugoslavs, and Poles follow close behind. Although Chinese men smoke almost as much as Western men, the negligible amount of smoking by Chinese women means that the country does not rank very high in overall per capita consumption. Nevertheless, China uses a quarter of the world's tobacco.

Societies urgently need to examine how to better control tobacco use—in both the present and the future generation of adults—for the current informational campaign is not working well. The basis of antitobacco action since the mid-1960s has been information aimed at educating smokers about their health risks and discouraging nonsmokers from starting. The campaign seeks through media coverage of scientific studies to persuade smokers to quit and children never to start. It tries to change society's attitudes so that the habit will be widely regarded as socially unacceptable. This approach has been tested in a few countries such as Finland, Norway, Sweden, and, to a lesser extent, the Netherlands, the United States, and the United Kingdom. It has been practiced de facto in China and many Eastern-bloc countries. The results, however, are decidedly mixed.

Smoking habits among young people are sometimes changing for the better, other times not. American, British, Norwegian, and Swedish children are less likely to smoke than they once were; and when they do smoke, they start the habit later in life. Elsewhere the news is less promising. More

young people than adults smoke in Eastern-bloc countries, in Canada, and in Egypt. In some schools surveyed in Santiago, Chile, two-thirds of the students smoked. Even in developing societies—among Polynesians, for example—smoking rates reach levels exceeding 50 percent in children.

The overall situation of antismoking efforts is at best a standoff in industrial countries and a rout in developing ones. At the current rate, Western countries will not see a major improvement in the health effects of smoking for many decades, but Eastern and developing countries will see a rapid worsening. It falls to world health leaders to bolster their antismoking efforts. Unfortunately, one key agency, the World Health Organization, allots less than one percent of its budget to this problem, although it calls smoking "the most important preventable adult health problem in the world." Its current budget for the mid-1980s has no funds for actively reducing tobacco's toll.

In the West, effective campaigns against smoking have to some extent fallen to grass-roots movements to protect passive smokers. These campaigns, which at present stop short of banning tobacco, include either the prohibition of smoking in public areas or the strict limitation of smoking to specified areas.

Such movements, however, do not address the problem of tobacco addiction nor can they protect developing fetuses, children, and teen-agers from their parents' smoke. Although parents can take this responsibility upon themselves, their addiction works against them. If parents fail to take responsibility, the only way to protect children will be to control the product itself.

William U. Chandler

Will economic growth improve the prospects of the next generation?

Most development aid assumes that boosting Third World economies will translate into other basic gains such as improved health, nutrition, education, and a falling birth rate. Yet a country like Malawi, which experienced more than 6 percent annual economic growth throughout the 1970s, still ranks fourth worst in the world in child health. At the same time, some very poor countries like China and Sri Lanka rank near the developed world in infant and child mortality.

More than 16 million children die each year from the combined effects of poor nutrition, diarrhea, malaria, pneumonia, measles, whooping cough, and tetanus. Virtually all these deaths occur in the Third World, and half to two-thirds could be prevented with relatively simple measures. These include nutritional education, breast feeding, oral rehydration (reversing diarrheal dehydration with simple sugar, salt, and water solutions), and immunization.

A major component of a campaign to fight malnutrition is the education of school girls and mothers in hygiene, oral rehydration, immunization, breast feeding, family planning—in short, in child health. Progress in this area has perhaps contributed most to improving the health of the world's children.

Countries that have attained both lower fertility and lower mortality rates also have high female literacy rates. Fortunately, the Third World has

Primary Care in the Gambia

The West African nation of the Gambia has inaugurated a relatively successful program to deliver primary health care. Villagers are trained for six weeks as health workers, then provided with simple tools of the trade: oral rehydration salts, antibiotics, bandages, antimalarial drugs, aspirin, and other curative items. They learn to recognize the signs and symptoms of measles, whooping cough, malaria, and cholera. Records of all cases are kept on simple picture sheets usable even by illiterate workers.

Workers are also educators; they teach mothers to administer the oral rehydration salts for episodes of diarrhea, and not to wait until the child is dehydrated. First contacts are followed up with home visits to make certain that recommendations are being followed and to explain how to prevent recurrence of diarrhea or other avoidable problems. Difficult cases are referred to a district health post staffed by more highly trained workers or to a regional hospital, which the parents can reach within a day by donkey cart and where a doctor is available.

Supervisors with two years of training monitor the work of five village health workers, visiting each village once weekly to assure that drugs are available, records kept, and preventive services performed. If special problems arise, regional medical professionals are alerted. This system enables the health ministry to respond quickly to any epidemic of measles or cholera and to dispatch an emergency team to give immunizations or to take other preventive actions, such as securing the water supply.

Vast disparities in outcomes, however, can be seen even within this tiny country. In the Arasemmi district, infant mortality is only 5 percent. But in the nearby Central district, which uses virtually the same approach, infant mortality averages 15 percent. Better administration in the Arasemmi region, and perhaps more positive tribal attitudes toward hygiene, account for the difference.

Public health has nevertheless improved throughout the Gambia. Measles and cholera outbreaks have been effectively contained. Malaria incidence in children has been reduced by dispensing chloroquine to feverish children during the rainy season, particularly when their resistance is low due to depleted food stocks from the previous harvest. Although primary health care has a long way to go in the Gambia, absence of epidemics in that country is a powerful indicator that the system is beginning to work. *W.U.C.*

Pedro Martinez, grade 5, United States

Studio in a School

made significant progress in female literacy. In 1960, 26 percent of the world's girls did not attend primary school; by 1982, this figure had been reduced to 17 percent. Children not in school continue to be found almost exclusively in countries with the highest child-mortality rates.

Controlling infectious childhood diseases has helped reduce mortality related to diarrhea, which causes deadly dehydration and malnutrition. For example, diarrhea frequently accompanies measles, and, theoretically, vaccinating 75 percent of a child population for measles would reduce diarrheal mortality 10 to 20 percent. Only about 40 percent of the world's children, however, have been vaccinated against measles, diphtheria, whooping cough, or tetanus. Full coverage against the major childhood infectious diseases would cost only $2 to $15 per child worldwide. To extend vaccination coverage to all the world's children would cost some $600 million to $4 billion per year.

The importance of water to child health, and the direct bearing that water wells now have on garden crop production and community development, is second only to that of female education. Water plays two important roles in malnutrition: Shortages not only reduce food production but also affect the body's ability to use food. Contaminated water causes diarrheal disease in children. When women walk up to three hours to get minimal water supplies, water becomes too valuable for washing, and an important defense against infection is lost. The strength of this relationship has led UNICEF to dedicate a quarter of its global budget to providing simple water supplies. In Ethiopia, water is the largest item in the UNICEF budget after relief.

Clean drinking water, unfortunately, has not been a high priority for many countries. Four-fifths of the rural populations of seventy-three African and Asian countries do not have access to clean drinking water. Most have no toilets or latrines. Worldwide, 1.3 billion people lack clean water and 1.7 billion lack adequate sanitation.

Poor families are caught in a trap: They need many children to help with the work and provide security to parents in old age. But by having more children, families share fewer acres of land, fewer liters of water, and less income per person. The only escape from this trap is having fewer—but more productive—children. Family planning improves the lives of children in two ways: by increasing the health care and educational services available per child and by making the survival of each child more likely.

Family planning has the greatest impact on infant mortality when it is used to prevent the highest-risk pregnancies. These include pregnancies to mothers under age twenty or over thirty-five, pregnancies spaced close together, and pregnancies to mothers who have already had several children. Families that minimize high-risk pregnancies lose fewer children and so do not need one or two extra as "insurance."

Family planning's contribution to child development is perhaps greatest on the social level, since high fertility translates into reduced living standards. Rapid population growth can overload a society's ability to provide classrooms and food. The World Bank estimates that Western countries

J.A. Premalatha Shamalee Perera, age 10, Sri Lanka — U.S. Committee for UNICEF

spend fifty times more per primary-school student than the least-developed countries. Yet, the school-age population of a country such as Kenya will double or triple by the year 2000. If such countries act to reduce population growth rapidly, the cost of educating their children can be cut in half over the next twenty-five years. Savings can be used to improve the quality of education, reducing the immense gap throughout the world.

Warding off death does not guarantee a decent life. Primary education is essential for understanding better health and agricultural practices, but as the relatively literate countries of Tanzania and Bolivia have shown, education will not compensate for lack of incentives in agriculture. Agriculture is the basis of rural economies, but as India has learned, the Green Revolution cannot compensate for infected bodies unable to make use of food. Clean water, as many failed projects have demonstrated, will not compensate for a lack of understanding of hygiene.

A strategy of integrated development to meet basic needs all across the Third World demands not only techniques that prevent death but also planning for food production, clean water, education, and, ultimately, health. This strategy can incorporate measures to counter drought through revegetation of desiccated lands. It is a strategy of investing in people, one that could truly revolutionize the prospects for child survival.

If such investments in the next generation make so much sense, why have more not been made? The reasons vary, but in many lands the necessary savings have been wasted by drought, misguided agricultural policies, corruption, and war. Investments in children also do not pay off for a long time, and most people have far more immediate needs. People in the Third World do sacrifice for their children, even to the extent of denying themselves food. Their margin of existence is simply too narrow to leave anything for investing in the future.

Industrial countries can siphon off part of their surplus to help those who have nothing extra. The outpouring of donations to famine victims suggests that people feel compelled to provide disaster relief. But disasters will grow, as will the costs of disaster relief, unless investments are made in family planning, health care, and education.

What is the state of the world's children today? Is the glass half full or half empty? An optimist would answer that the infant mortality rate has been halved. A pessimist would answer with the fact of famine. A realist would be buoyed by the statistical improvement in infant mortality, but sobered by the fact that, thanks to explosive population growth, as many children suffer and die today as did twenty years ago. Our progress has only offset the growth of our problems.

When development relief does more than just stave off famine, when it is invested to provide benefits for years to come, then savings—in lives and money—will be made.

William U. Chandler

Authors

Lester R. Brown is president of Worldwatch Institute, an independent, nonprofit research organization created to analyze global problems. With Worldwatch colleagues **William U. Chandler, Christopher Flavin, Jodi L. Jacobson, Cynthia Pollock, Sandra Postel, and Edward C. Wolf,** he authored *State of the World 1986: A Worldwatch Institute Report on Progress Toward a Sustainable Society,* edited by Linda Starke and published by W.W. Norton & Company, New York and London, 1986.

Left to right: Sandra Postel, Christopher Flavin, Jodi Jacobson, William Chandler, Ted Wolf, Cynthia Pollock, Lester Brown

Artwork was provided by the U.S. Committee for UNICEF and by the Studio in a School Association, a not-for-profit organization that places artists in New York City public elementary schools to work with children.

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Gabriel Cortez
Colombia
Age 4

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Picnic *à la dauphine*

The early ancestors of the dolphins and porpoises were land mammals that returned to the sea some 20 million years ago. The bottlenosed dolphin, commonly seen along the coasts of the United States, reveals part of its distant past when it surfaces twice each minute for a breath of air. But most of the bottlenosed dolphin's life is spent beneath the surface, often in pursuit of the fifteen or so pounds of fish it eats each day.

When they hunt, the dolphins send out a variety of whistles and clicks to find fish by echolocation. They also communicate with one another—each dolphin makes a distinctive sound that enables the others to recognize it in dark or murky waters—as they pursue and encircle schools of small fish.

Along the coast of Georgia and the Carolinas, bottlenosed dolphins have learned a fishing technique, observed by local

fishermen and a few scientists, that briefly returns them to the world of their early ancestors.

With precise timing, two or more dolphins herd a school of fish toward a mud flat at low tide. The massive bodies of the dolphins, which often weigh 300 to 400 pounds, push up a wave that bursts onto the beach. Fish caught in the wave are stranded, and the rush carries the dolphins out of the water. They roll to the right, dig in a pectoral, and (see next page) snap up the fish, as if they were pieces of popcorn. The dolphins seem clumsy out of the water, appearing to us, perhaps, as swimming humans must appear to them. After their picnic on the beach, the dolphins slide back into their element and gracefully glide away.

These dolphins were photographed along the coast of South Carolina near Hilton Head Island. *—Alan P. Ternes*

Photographs by Peter Cram

Brittlebush blooms on a hillside in the Sonoran Desert, left. A blister beetle feeds on the flowers, below.
John Alcock

Conjugal Chemistry

For a species of blister beetle in Arizona's Sonoran Desert, sex is an investment in time and toxins

by John Alcock

D. Wilder

In the Sonoran Desert of southern Arizona, ample winter rain has encouraged the brittlebush to bloom with abandon. Steep hillsides, in most seasons marked only by the occasional giant saguaro cactus and rocky outcrop, are covered with yellow, daisylike flowers in the desert spring. Cactus wrens call from the tops of spiny chollas; their lugubrious "chug-chug-chug-chug" carries to the tops of the desert ridges from the plain hundreds of feet below.

From one of the ridges, I watch a small beetle cruise high above me, its black wing covers raised in a V above its body. The insect swoops down and zigzags in to crash-land in a patch of brittlebush growing along the ridge. Like an insect Evel Knievel, it is quickly on its feet again, and scrambles through a cluster of brittlebush flowers. The shrub the beetle has chosen from among the hundreds growing on the ridge is already occupied by several dozen of its brilliant black-and-orange fellows. No other nearby bush is similarly ornamented. The bush's occupants belong to the species *Lytta magister,* in the family Meloidae. Meloids are commonly known as blister beetles.

The aggregated beetles, which are enjoying an aesthetic feast of brittlebush flower petals, are of all sizes, from slim creatures about half an inch long to great bloated animals four times as long and fifteen times as heavy. The degree of size variation is unusually great in *L. magister*, although there are still more extreme cases, such as brentid beetles that vary in weight by a factor of twenty-five. Many of the beetles in the brittlebush are mating even while gorging on yellow petals. Curiously, the mating pairs appear to have sorted themselves with some reference to size. Small beetles tend to be coupled,

D. Wilder

Like the three mating sets below, most of the beetles pair off according to size. During copulation, which may last more than twenty-four hours, the male imparts sperm, nutrients, and cantharidin, a toxic chemical used for defense, to the female. A mating pair, right, continue to process brittlebush flowers.

John Alcock

medium-sized animals have paired off, and large females with abdomens swollen with huge ovaries are often linked to equally massive males.

Despite the old saw that opposites attract, nonrandom pairings within animal species are far more likely to involve individuals with similar, rather than dissimilar, attributes. The most common expression of this phenomenon is the pairing of individuals of about the same size, or as it is formally labeled, positive assortative mating by body size. We know, for example, that if a human male is unusually tall, his wife is probably a taller-than-average female. Conversely, short men often marry relatively short women. Similar-sized individuals pair off in a host of other species, including certain snapping shrimp, aquatic isopods, and even some protozoans. *L. magister* is yet another example of the same phenomenon. I measured body sizes of a large sample of mating pairs and statistically confirmed what is obvious to even a casual observer—size-matched pairs are more numerous than mismatched couples.

The apparent selectivity in mate choice in beetles raises an evolutionary point: How does copulating with a partner of similar dimensions promote reproductive success? This question assumes that if individuals expend time and energy seeking out mates similar to themselves and rejecting others, they must derive some counterbalancing reproductive advantage that will compensate them for their choosiness. If not, natural selection would surely favor individuals that conserved their time and energy by accepting partners without regard to body size or any other attribute. The less choosy types would, so the argument goes, be able to convert their savings in time and energy into more offspring, and over time their genes would swamp those that fostered assortative mating. But students of assortative mating have had a hard time discovering just what advantage individuals gain by selecting mates of similar size. Conducted with researchers Scott Snead and Neil Hadley, my study of *L. magister*'s behavior, the design of its reproductive system, and the biochemistry of its tissues has suggested an answer to the puzzle of assortative mating in this species.

The natural history of the *L. magister* blister beetle is still incompletely known, but we can sketch the main features of its life cycle. In certain portions of the Sonoran Desert, adults appear only in March and April. The beetle is never common, even in years when winter rains have brought a profusion of its favored food plants—the short-lived desert annuals and brittlebush flowers. A random walk through the desert almost never yields even a single sighting. If, however, one searches the mountain ridges that push up from the desert flatland, an encounter with the beetle is more likely. And when one beetle is found, many others are sure to be located nearby, because the animals seek out the company of others on their food plants at the tops of desert hills and mountains.

The striking coloration of blister beetles is a warning not to touch (or eat). Manhandled beetles release droplets of haemolymph, or insect blood, from their leg

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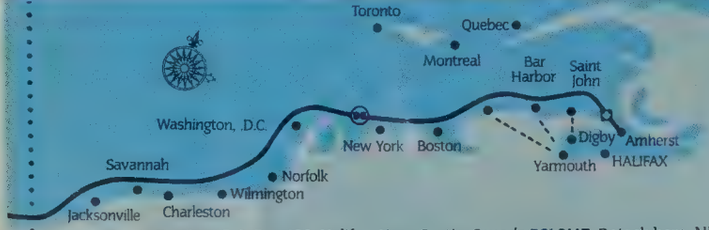

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joints. This sticky yellow fluid contains the chemical cantharidin, a thoroughly toxic defensive substance that blisters human skin—which explains the common name of *Lytta* and its meloid relatives. When ingested, cantharidin severely irritates and damages the digestive and urogenital tracts. In the course of their investigations of blister beetles, James Carrel, now of the University of Missouri, and Thomas Eisner of Cornell University were originally tempted to test the repellent properties of their subjects personally, but they abandoned the idea after reading that ingested cantharidin causes *erections douloureuses et prolongées*. Although their decision to forgo a cantharidin taste test was eminently sensible, other humans in the past have enthusiastically consumed concoctions composed in part of dried and crushed blister beetles. The species of choice was *L. vesicatoria,* a common European blister beetle known as Spanish fly, an entomological misnomer that has persisted to the present. Spanish fly, a supposed aphrodisiac and an ingredient in "love potions," actually produces urinary tract irritation, which some men have confused with erotic stimulation.

Blister beetles produce cantharidin to deter potential enemies, which range from birds and small mammals to ants and other predatory insects. Cantharidin works well against ants, which recoil from blister beetle haemolymph. Vertebrates, too, may find these insects repugnant, but I have seen some species of flycatchers snap them up and, after thoroughly pounding them on an ocotillo limb, eat them. I have also found discarded wing covers and heads of eaten blister beetles on the ground, where they had been dismembered, probably by a rodent. So although cantharidin may be an effective antipredator device, it is not perfect.

I believe that the capacity of the beetle to produce and use cantharidin as a defensive weapon is the key to understanding much of its mating and other social behavior. The fact that blister beetles gather together in conspicuous clusters is surely related to their noxious properties. Tendencies to aggregate have evolved independently in many other species of brightly colored, toxic insects. When a naive predator attacks a member of the band, it will be quickly educated to the realities of life and will immediately apply what it has learned to the other members of the aggregation. A blister beetle that joins a feeding mass on a brittlebush will be safer from predators. Thus a blister beetle is compensated for spending the time and energy to locate a cluster of its fellow beetles.

Once they have gathered together, the members of a blister beetle congregation have access to any number of potential mates, and males take full advantage of this opportunity. Whereas the primary goal of females in an aggregation appears to be to eat as much as possible, males seem to be motivated largely by the drive to acquire a mate. A male goes from one female to the next, mounting each in turn and rhythmically stroking his consort's antennae. Females rarely respond to this display, but instead calmly continue working their way through one flower petal after another. Occasionally, however, a female proves receptive and permits the male to couple with her. Harpoonlike barbs on the male's aedeagus, or penis, help link the male and female firmly together for periods in excess of twenty-four hours. Not that they permit copulation to interfere with a good meal, for the two continue to eat and excrete for the duration of their mating.

Cantharidin comes into play during the prolonged period of conjugal attachment. Male meloids have a large, multilobed abdominal gland. This organ, known as the accessory gland, provides substances that are passed to the female during copulation as a spermatophore, a packet consisting largely of sperm and protein supplemented with other material. The female has a special sac associated with her reproductive tract that receives the spermatophoral materials. Among the substances transferred from male to female blister beetles is the chemical cantharidin. Adult females of one European species of blister beetle cannot even manufacture the toxin themselves and have to obtain their entire supply of cantharidin from their mates, which are able to synthesize the toxin as adults. The time involved in manufacturing and then passing the chemical to a mate is probably one of the reasons for the length of copulation in *L. magister*.

Females may use cantharidin transferred from their mates for several purposes. They may extract the substance from the spermatophore and pass it to the haemolymph for self-protection. Or, because females lay their eggs in the soil where the eggs are vulnerable to digging ants and other insect predators, they may use male-donated cantharidin to coat the eggs, making them ant proof, a hypothesis being tested by Eisner and Carrel.

When the eggs hatch, the first-stage grub, or triungulin, is a minute but highly active larva with well-developed grasping legs. The triungulin makes its way to a flower where it sits and waits for a solitary bee to arrive. The triungulin then grasps

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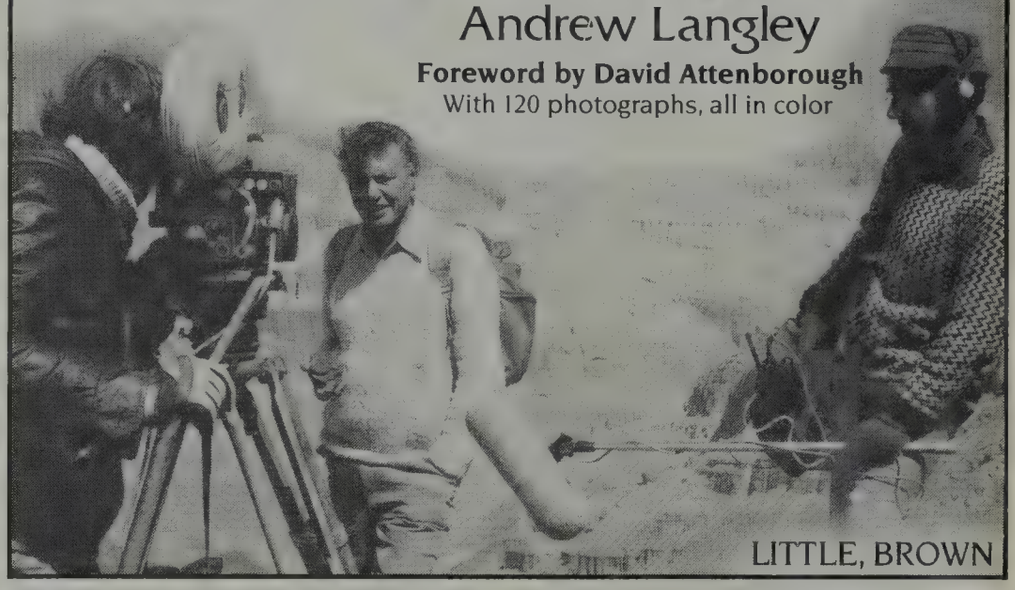

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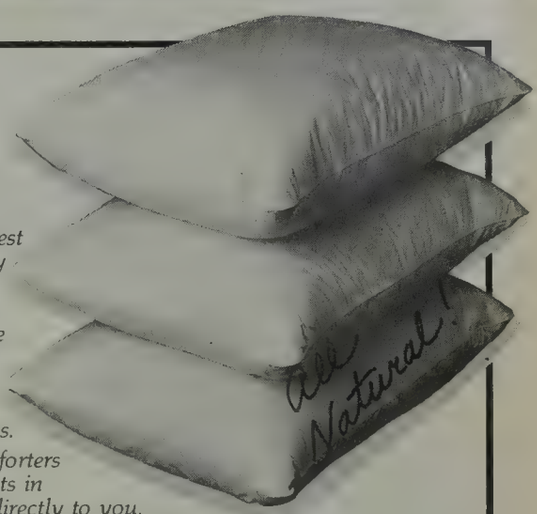

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the bee and hitches a ride back to the host's nest. Deposited in a cell at the end of the underground nest, the parasitic beetle larva will destroy the bee's egg and eat the nectar and pollen collected by the bee to feed her offspring. A year later the adult blister beetle will emerge from the soil in time to mate and contribute to a new generation of bee parasites.

The range of body sizes in the blister beetle is probably largely the product of differences in the luck of the draw experienced by triungulins. Some are carried to the nests of bees that produced large brood cells laden with food, while others are transported to a meager food supply and so grow up smaller than their well-fed fellows. A large male, with his large accessory gland, can supply large amounts of cantharidin, and perhaps other useful substances, in the big spermatophore. He can also make his contribution relatively promptly, freeing the female to go about her business with an ample cantharidin supply for her personal protection or for that of her eggs. Thus we can predict that all females should prefer large males as partners.

Males, too, probably prefer large females. The swollen abdomen of a female bulges with ovaries filled with dozens or even hundreds of eggs. The larger the female, the more numerous her eggs. Males that mate with such females should secure more egg fertilizations in return for their investment of one to two days of copulation and the donation of a cantharidin-rich spermatophore. They can be expected to leave more descendants than do less discriminating males. Thus a preference for large body size should be the norm for the male population.

Because both males and females gain by mating with as large a partner as possible, large individuals tend to pair off, leaving medium beetle with medium beetle, and small with small. Therefore our original hypothesis, that there must be some reproductive benefit in selecting a matched mate, may not be correct. Positive assortative mating could suit blister beetles, not because they gain by choosing similar-sized partners, but because they all possess the same preference for largeness, differing only in how closely they themselves match the preferred standard.

If this is correct, we should find assortative mating in other species whose males also vary in size (and spermatophoral donation) and whose females vary in size (and fecundity). Another Sonoran Desert meloid, *Tegrodera aloga,* seems to meet these conditions. It appears later in the spring in bands that march across the desert flatland eating the grasses and tiny

annuals that begin to set seed at this time. Males of *T. aloga* run from female to female, courting each in turn in an elaborate tête-à-tête. While the male faces the female, he repeatedly wraps his antennae around hers and draws them into two deep grooves on his head. Most females fail to respond to this exotic courtship stimulation, but enough do so that mating pairs can be easily found in the huge aggregations of several thousand beetles that come together during the breeding season. Measurements of mating pairs of this species reveal absolutely no positive assortative mating by body size.

This is unexpected, because males of this species do indeed offer their mates a large, cantharidin-loaded spermatophore and both sexes vary substantially in body size. But there is one major difference between *Lytta magister* and *Tegrodera aloga* that may hold the key to understanding why only one of these species mates assortatively. Instead of spending twenty-four to forty-eight hours mating, as *Lytta* does, a male *Tegrodera* makes his spermatophoral donation in just four hours. So even though males of both meloids transfer large amounts of valuable cantharidin to their mates, it costs the male *Lytta* more to provide the nuptial present. That cost is time, time that might have been used to find another receptive female during the male's short life. Because a male *Lytta* requires one or two days per mating, he must fertilize as many eggs per mating as possible. A large male may pass up a small receptive female to seek a large mate that can give him a greater return for his relatively costly investment per copulation.

The comparison between the two meloids suggests that conditions for assortative mating in animals may be fairly restrictive—not only must size variation be related to variation in the male's capacity to provide useful resources to a mate but the cost of making the donation must be considerable. Rigorous tests of this hypothesis would help illuminate an important subject in behavioral ecology; we still know very little about the extent to which males and females choose carefully among potential mates within their species. Even less is known about the factors that influence male choice when it occurs. I am confident that many cases of discriminating mate choice will eventually be found among the insects, particularly in species in which males transfer useful chemicals, along with their sperm, during copulation. Having the "right chemistry" may well prove to be more than just a metaphor in the sexual life of *Lytta magister* and similar insects. □

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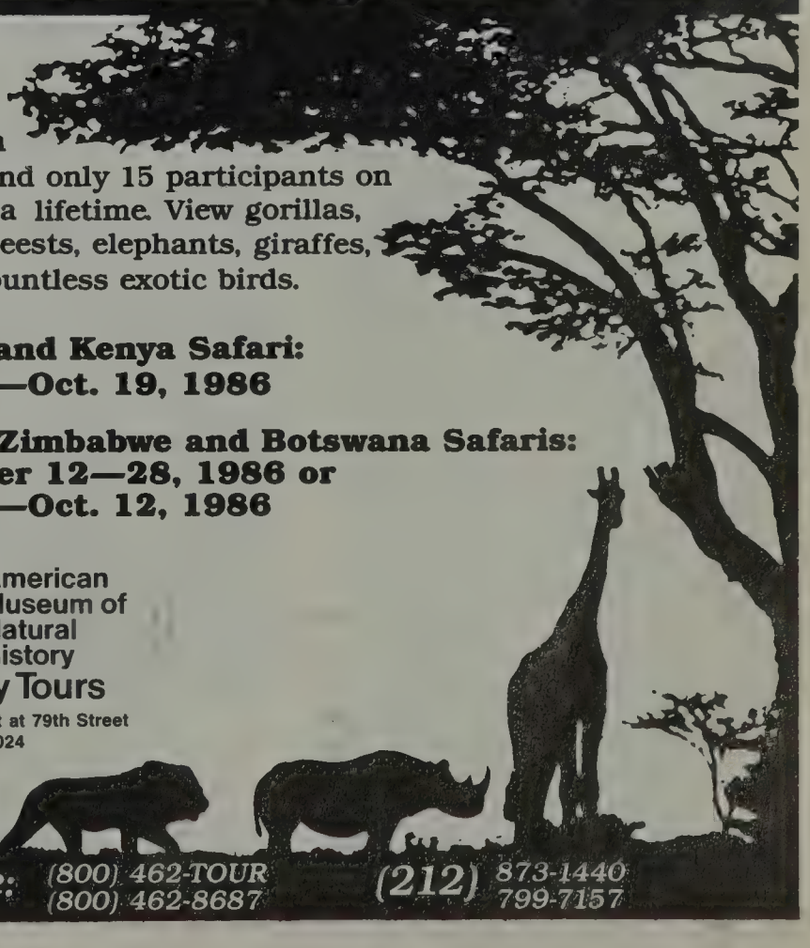

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April Is Not the Cruelest Month

by Thomas D. Nicholson

The planets move decisively out of their winter doldrums this month, significantly improving their positions and their brightness. Both morning and evening skies reap the benefit, but morning has the edge as Mars, Jupiter, and Saturn show off their best. Saturn rises earliest, an hour or more before midnight; Mars will rise slightly more than two hours behind it; and Jupiter just before dawn.

Toward sunrise later in the month, the three are strung out impressively from the east, where Jupiter is above the horizon; through the south, where Mars adds its color to Sagittarius; to the south-southwest, where Saturn plays off its brightness against the nearby ruddy Antares, of Scorpius. Jupiter is clearly the brightest of the three as the month begins, with nothing in the sky to rival it. Mars and Saturn are reasonably well matched. Mars's coming opposition this summer is bringing the earth and the planet closer together more rapidly now, and the effect is beginning to show in the brightening of Mars. At the end of the month Mars is clearly brighter than Saturn but still comes off a poor second to Jupiter.

Helmut Wimmer

Comet Halley comes closest to the earth during this visit (39 million miles away) on April 11. As the comet approaches, moves past, and then away from the earth, our view of it changes, as illustrated above. Seen from the earth on April 1, the comet is to the sun's right, placing it in the morning sky. By month's end, the earth and the comet are separating rapidly. The comet is then to the sun's left, placing it in the evening sky, where it sets after sundown. The changing view from the earth also makes the comet's tail swing around the sky during the month.

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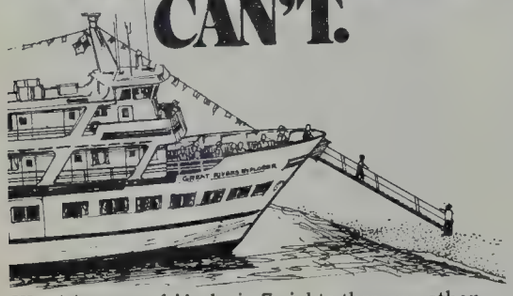

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There is a respectable morning elongation of Mercury this month; it is not the best but is still a welcome one. From midmonth, when Mercury reaches its greatest distance to the sun's right, the planet brightens by a full magnitude, improving the sight for those with clear, unobstructed eastern skies. Look very low to the east at dawn in order to see it.

Venus is slowly increasing its easterly elongation, making it easier to see low in the west during evening twilight. And its great brightness should make it a good target for sky watchers this month.

Events in the calendar below are given in local time unless otherwise indicated.

April 1: Today's moon (last quarter a

The spring Sky Map shows the sky for the months of April, May, and June from latitude 40° north at the evening hours given below. To use the map, hold it vertically in front of you with south (S) at the bottom and match the lower half of the map with the stars you see when you face south. As you face in other directions, roll the map to bring the corresponding compass direction to the bottom. The stars move west continuously during the night. By morning (before dawn), stars on the western half of the map will have set, those on the

30 P.M., EST) rises an hour after mid-
ght, remains up until midmorning, and
en rises again about two hours after the
y ends. It is in Sagittarius, not far from
ars, the bright, reddish object to its
ght.

April 2–8: Moonrise occurs later in the
orning each day, and the moon remains
nger in the daytime sky, as it wanes

Helmut Wimmer

eastern half will have moved into the west, and new stars (those of the fall evenings) will have risen in the east. The map represents the sky at about 2:00 A.M. on April 1; 1:00 A.M. on April 15; midnight on April 30; 11:00 P.M. on May 15; 10:00 P.M. on May 31; 0 P.M. on June 15; and 8:00 P.M. on June 30. Add one hour for daylight time. The map can be used for an hour or more before and after the times given.

through its crescent phase and moves through Capricornus, Aquarius, and into Pisces. It drifts past Jupiter, in Aquarius, on the 5th, so it will be near the bright planet on the 5th and 6th. Our last view of the moon as a morning object should be on the 8th.

April 7: Mercury is near the moon this morning, but not yet at its best in the morning sky. It will be much brighter toward the end of the month.

April 9: New moon is at 1:08 A.M., EST. Today, the first of the year's four eclipses occurs, a partial eclipse of the sun, visible from Australia, New Zealand, and Papua New Guinea.

April 10: Venus is slowly improving as an evening star; you might be able to see it in late twilight tonight just below the lower "horn" of the slim crescent moon.

April 11: Comet Halley passes nearest the earth today at a distance of 39 million miles. This is the second close approach the comet makes during its 1985-86 appearance (the first was on November 28, 1985), but this one clearly favors viewers at southerly locations, below 30° north latitude.

April 13: The moon is farthest from the earth (apogee) this morning. It will be up as a crescent in Taurus after sundown, but the stars of the Bull will be too dim and low to see. Mercury is at greatest distance to the sun's right (greatest westerly elongation), placing it best as a morning star. Its increasing brightness over the next two weeks gives us a fair shot at seeing it.

April 16: Gemini and the moon are up in the west when darkness falls.

April 17: First-quarter moon is at 5:35 A.M., EST.

April 18: The moon is just crossing the border between Cancer and Leo.

April 19: Regulus, the Lion's brightest star, is just below the moon.

April 20–23: Watch the moon pace off the distance between Regulus and Spica, the next bright star along its route. Spica is about two and one-half hours east (to the left) of Regulus, and it takes the moon four days to cover the distance.

April 24: Full moon is at 7:46 A.M., EST, and the second eclipse of the year takes place, close on the heels of the solar eclipse two weeks ago. Where the full moon is up, it will be seen passing through the earth's shadow, causing a total lunar eclipse. The beginning of the partial phase occurs at 6:03 A.M., EST, after moonset in the northeastern part of North America, but it can be seen elsewhere. Total eclipse (when the moon is fully immersed in shadow) begins at 7:10 A.M., EST. Part of totality can be seen in western states, and the entire umbral eclipse is visible from

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April 26: The star Antares, Saturn, and the moon are in conjunction with one another today, and they all rise together in the east from about 9:00 P.M. on. Daylight time begins tonight for communities that make the change.

April 27–29: The waning moon should help in finding Sagittarius as it slips through the constellation on these nights. It dips under Mars during the night of the 28th when both moon and planet are just above the Archer's easily recognized "teapot" of stars.

April 30: By the end of the month, the moon is again at last-quarter phase, at 10:22 P.M., but it doesn't rise until after 1:00 A.M. on May 1, in Capricornus.

One More Chance

When choosing a title for this month's comet story, I was tempted to call it "One Last Chance." But then I remembered the old line we used to see on gasoline stations not too long ago: "Last Gas Before Parkway," and the response of the guy who opened up another station nearby: "Last Gas Before the Last Gas Before the Parkway!" So I thought I should find another title. April will give us one more *good* chance, but for very avid comet hunters, with the right equipment and the determination, there will be another chance in May and another in June, and if they are especially well favored with equipment, on into 1987 and 1988, and so on.

"One More Chance" is a compromise. April *is* a month of opportunity for ordinary Comet Halley watchers, and probably the last good one they will have. It offers the best and the worst viewing conditions during the comet's close approach early in the month, depending on your location; a very rare chance to see a comet tail swinging around our sky as the comet moves past the earth, and one more chance at seeing it in the evening sky late this month.

Although comet observation during April favors Southern Hemisphere viewers, by month's end those in midnorthern latitudes will enjoy a view about as good as that of early January, but only for a few days.

The best viewing in early April, when Comet Halley makes its long-awaited close approach to earth (39 million miles away), is in the morning sky from the tropics or near-tropics and the Southern Hemisphere. The farther south you are, the better, although once you get about 30 degrees south of the equator, going farther won't make much difference. From southern Florida, for example, the comet can be seen only low in the south for an hour or so before dawn on April 5 or 6, but for Rio de Janeiro or Australia it will be well up in the sky from east through south to southwest from shortly after midnight until dawn. Even where the comet is so low that its fuzzy and brighter head is obscured by horizon haze, its tail might be seen curving dimly up through the clearer and darker sky above.

Clear, dark, moonless skies are a must (the morning moon will be a problem until the 4th), and it will be helpful to have a good map of the comet's position among the stars and to use wide-field binoculars (such as 7 × 50) for searching. For those fortunates who enjoy these conditions from the right location, the comet's coma (the glowing sphere of gas surrounding its tiny nucleus) is bright enough to see with the unaided eye, half the size of the full moon in binoculars, while the dimmer tail can be traced out to a length at times greater than that of the Big Dipper.

But all of this is lost to viewers in central and northern North America because the comet is so far south of the equatorial plane in early April that it can't climb high enough in the sky during dark hours to be seen. Only its tail, if we are lucky, stretching away to the south, may give it away. But for northern viewers, their turn *does* come late in the month.

Two key dates in the April comet drama are worth remembering, the 11th and the 17th. On the 11th the comet is nearest the earth, and on the 17th it becomes an evening object. The close approach on the 11th offers most to viewers in the southerly locations. The comet will be brightest on that date, even though its tail will not be longest. As the earth and the comet rush past each other at a combined speed of more than 1,000 miles per hour on April 11, our perspective of the tail changes rapidly. The tail will look longest in early April, and from then to the end of the month, its direction in our sky will swing around from northwest through north to northeast, even though it always flows away from the sun. Southerly viewers who can keep the comet in sight throughout most of the month will be able to see this effect nicely.

The comet's return to the evening sky after the 17th follows its passage through opposition from the sun. The earth then moves between sun and comet, offering northern viewers one more chance at "evening sky" watching. Toward late April the comet moves rapidly northward through the stars into familiar and more readily seen constellations in our northern skies, keeping it above the horizon for

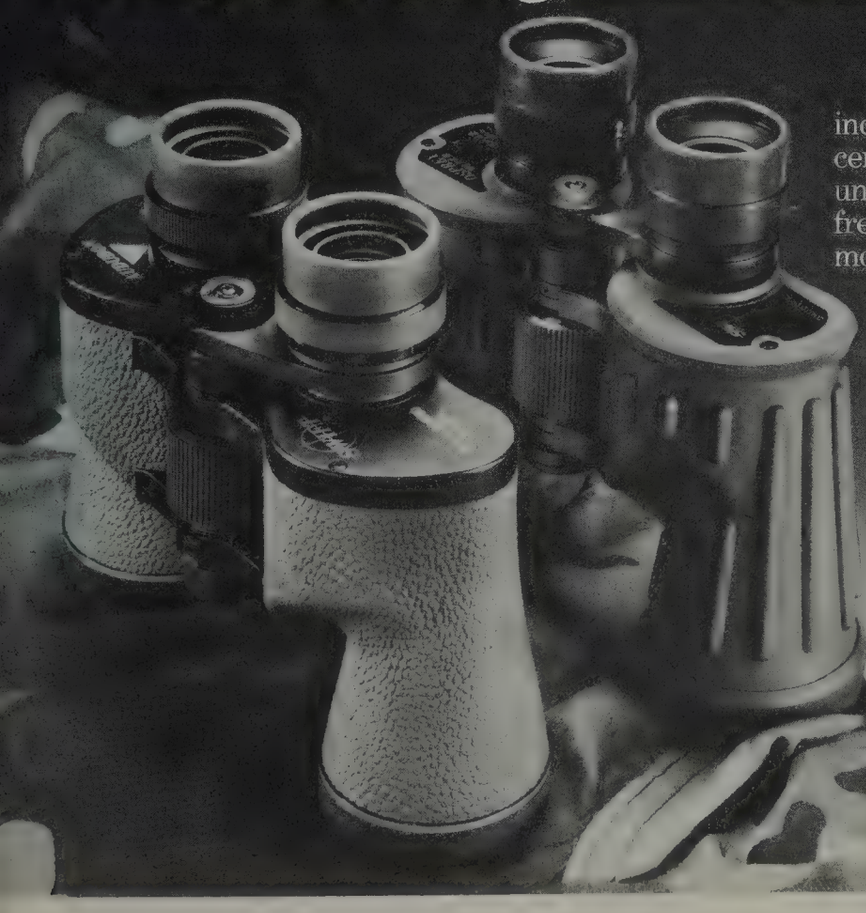
Helmut Wimmer

onger hours during the night, and visible rom shortly after sundown on. Although t is moving rapidly away from the earth nd sun by then, dimming and shrinking oticeably, it will be as bright or brighter, nd its tail better displayed and longer, han when we saw it from the northern nidlatitudes in December and January.

Comet Halley was an easy binocular bject when last in our evening sky, and it s again, late this month throughout the United States. All you will need is a good star map on which to locate its position, good binoculars, and a little patience and luck with the weather. Any clear evening after the 25th or 26th (when the waning moon leaves the early evening sky dark enough) should be good. And April evening temperatures should be much more conducive to patient comet searching than they were on those chilly nights of December and January. □

The position of Comet Halley improves for Northern Hemisphere viewers as the object moves north through familiar constellations. The best viewing will be from about April 25 through May 12 when the comet will be an evening object and moonlight will not interfere with binocular viewing. Southern observers will have their best conditions before dawn from about April 5 through midmonth.

Almost as good as a bird in hand.



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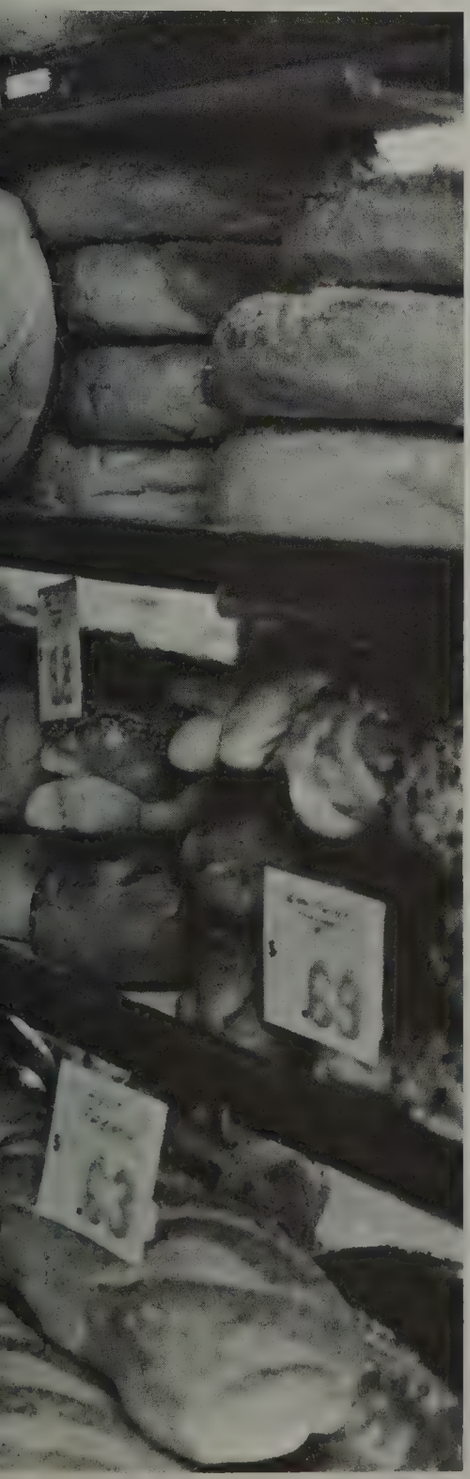

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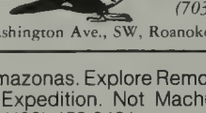
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New Life from Neblina

Photographs by Robert Noonan

the rain forest along the Brazilian-ezuelan border, a system of "table-mountains is all that remains of an ent plateau. One such mountain, ro de la Neblina, rises 9,000 feet above surrounding jungle floor and is called Mountain of the Mists because a e cloud cover frequently obscures its ts. Since 1984, Neblina has been the ect of an exhaustive floral and faunal ey sponsored by Venezuela's Founda-for the Development of the Physical, Mathematical, and Natural Sciences. Research teams, including scientists from the American Museum of Natural History, the Smithsonian Institution, the New York Botanical Garden, and the Field Museum of Natural History, and funded in part by the National Science Foundation, have returned from the field with thousands of specimens, many of them previously unknown to science.

Pictured here are three of the life-forms that inhabit Neblina. The ancestors of these and perhaps thousands of others collected there may date back to the time when the mountains were one large plateau. As the plateau eroded, the mountains became separate ecosystems, independent of the surrounding rain forest. By comparing the species found on Neblina with their better-known relatives, scientists hope to learn more about the evolutionary and geologic history of the Mountain of the Mists.

Marshall Schwartzman

This inch-long black frog represents an entirely new genus, tentatively placed in the family Leptodactylidae by its finder, Roy McDiarmid of the U.S. Fish and Wildlife Service. This specimen was found nesting under wet moss beside a boulder. McDiarmid found eight others in an adjacent boggy meadow. Once the frog has been identified and named, one individual will be chosen as the "type specimen," the standard of reference for all future study of this species.

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Another new genus found at Neblina is a catfish, discovered in a river near the base of the mountain. Entomologist Paul Spangler of the Smithsonian Institution inadvertently captured this specimen with a net while looking for water beetles. The "beard" on the fish's snout has never before been seen on a catfish, according to Carl Ferraris, an American Museum ichthyologist who originally identified the fish. Because neither Ferraris nor any other scientist has been able to observe the fish in its natural habitat, the function of this beard is as yet unknown. It occurs only in adult males, and Ferraris says it may have something to do with courtship or mating.

In a rotting log near the base camp, scientists collected a specimen already familiar to science: a parasitic, carnivorous fungus, which had invaded the larva of a click beetle. According to Roy Halling of the New York Botanical Garden, who collected this specimen, the larva ingests the fungal spores along with other organic material on which it feeds. Once inside, the spores germinate and attack the larva, using its body as food and eventually killing it. In this photo, the fungus has consumed the entire larva except for the outer shell. The vertical sprouts contain the fungus's reproductive organs; the wind will disperse the spores produced at the tips.

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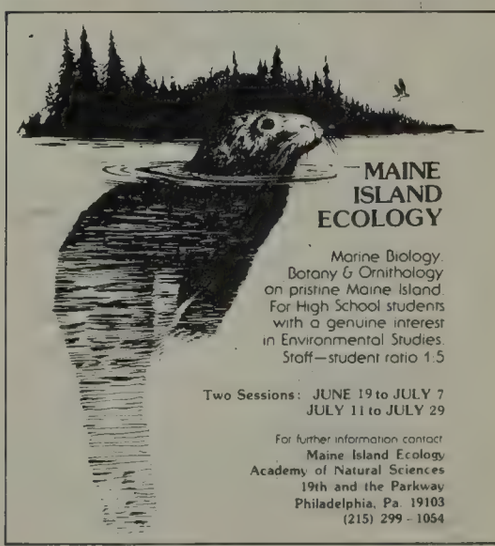

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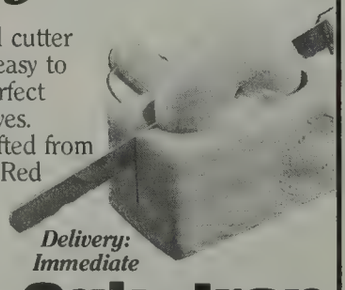

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At the American Museum

Caribbean Month

April is *Caribbean Month* at the Ame ican Museum. Each weekend the Peop Center will feature activities on Cari bean themes. For a complete list of acti ties call (212) 873-1300, ext. 514 or wr for a free flier to Caribbean Month, D partment of Education, American M seum of Natural History, 79th Street Central Park West, New York, New Yo 10024.

Symphony of Steel

On Thursday, April 10, at 7:30 P.M. symphonic steel orchestra, composed twelve family members, will fill the Ma Auditorium with the melodious sounds the Caribbean "pans" (steel drums). T family's drums were designed and bu by Herman "Rock" Johnston, found and leader of the group. Johnston h shaped and tempered thirty-six metal p cussion instruments, until each produce different note. This wide range of not and tones allows the group to play ever thing from Calypso rhythms to hym modern pop songs, and selections fr Handel's *Messiah*. For additional formation about this free program c (212) 873-1300, ext. 514.

Dances of China

Colorful costumes and music from d ferent time periods will highlight a l ture/demonstration of traditional a contemporary Chinese dances on Sund April 6, when the Young Dancers perfo at the Museum. Members of the trou will narrate the dances in both Engl and Chinese. *Dances of China* is free a will take place at 2:00 and 4:00 P.M. in t Kaufmann Theater. For additional formation call (212) 873-1300, ext. 55

The Song of Songs

The *Song of Songs,* ascribed to Ki Solomon, is both a sacred religious t and a cycle of love poems. It has been cited and revered for more than 2,0 years. On Thursday, April 10, storytel Diane Wolkstein brings these anci words of love and lamentation to life she performs her own translation from t Hebrew. The program is $6.00 for me bers and $10.00 for nonmembers and v take place at 7:30 P.M. in the Kaufma Theater. Tickets must be ordered in a vance. For additional information c (212) 873-1327.

Jews of Yemen

In a documentary to be shown Thursday, April 17, Johanna Spec

es the viewer on a journey in time from marriage of the Queen of Sheba and g Solomon, to the days when the Jews Yemen lost their kingdom, to modern- Israel, where Jews of Yemenite de- nt live. The film shows traditional wed- g preparations, costumes and jewelry, cational activities, male and female es, food preparation, social events, mu- and dance. Spector will introduce the n and answer questions from the audi- e. The program will take place at 7:30 . in the Main Auditorium. Tickets are 00 for members and $6.00 for non- mbers and must be ordered in advance. additional information call (212) 873- 7.

gles and Owls

Live eagles and owls will visit the Kauf- nn Theater on Sunday, April 13, when dlife lecturer Bill Robinson presents a nily members' program on birds. Rob- on will discuss the hunting techniques eagles, how an owl's vision and hearing ke it an ideal nocturnal hunter, the bitats and conservation of eagles and s, and more. The program, for mem- s only, will take place at 11:00 A.M., 30 P.M., and 2:00 P.M. Tickets are free must be ordered in advance. For addi- nal information call (212) 873-1327.

e Music of Duke Ellington

On Sunday, April 20, in the Kaufmann eater, the Museum presents a program noring jazz great Duke Ellington, who uld have been eighty-seven years old on ril 29. Compositions of various New rk jazz musicians including Count sie, Duke Ellington, Thelonius Monk, a Fitzgerald, and Billie Holiday will be formed by the Metropolitan All Stars. e tickets can be obtained after 12:00 . on the day of the show at the Kauf- nn Theater ticket booth. The perfor- nce will take place twice at 2:00 and 0 P.M. For additional information call 2) 873-1300, ext. 514.

the Planetarium

Starborn: Earth's Odyssey through ne and Space, the Hayden Planetar- n's newest Sky Show, takes the audi- e back five billion years to a time when earth and sun were cosmic clouds. The dience is taken through eons of time to ness the evolution of our living planet m a gaseous, to a liquid, to a partly d state. Torrential rains, volcanic ac- ty, crustal movements, and other ces that have shaped the earth are de- ted and historic human beliefs and in- ries about our planet are explored. Due to popular demand *Halley's met: Once in a Lifetime* has been ex- ded and will run concurrently with *arborn* until April 27. For show times d prices of both shows call the Planetar- n at (212) 873-8828.

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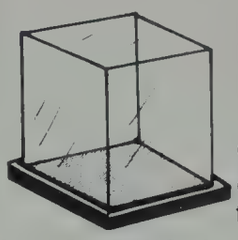

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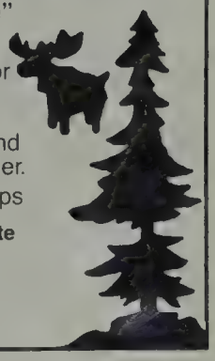

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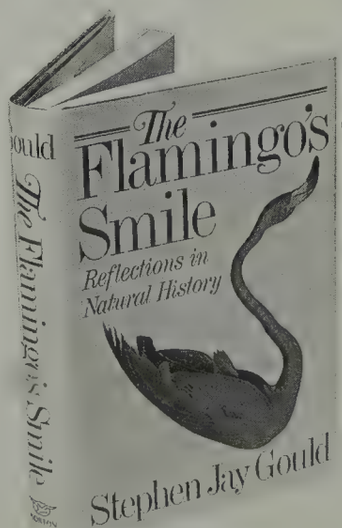

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Members' Book Program

Big Thicket, Texas

Robert H. Mohlenbrock

When the Tonkawas, Kanankawas, and ddo Indians roamed freely in what is w eastern Texas, a dense forest tched for more than one hundred miles theast of the present-day city of Hous-. To the Indians it was the Big Woods, Anglo-Saxon settlers who arrived ly in the 1820s called it the Big Thicket cause of its nearly impenetrable shrub er.

Harris B. Parks, who inventoried the nts and animals of the Big Thicket for Texas Academy of Science during the 30s, estimated that the forest originally vered 3.5 million acres, a region about size of the state of Connecticut. After re than a century of intensive lumber-, which began in 1850, and the inroads oil interests and real-estate developers, Big Thicket has been fragmented and luced to about 300,000 acres. Although bloitation of the forest continues today, National Park Service has been able to aside several isolated tracts totaling 000 acres as the newly designated Big icket National Monument. Another tion falls within Sam Houston Na-nal Forest.

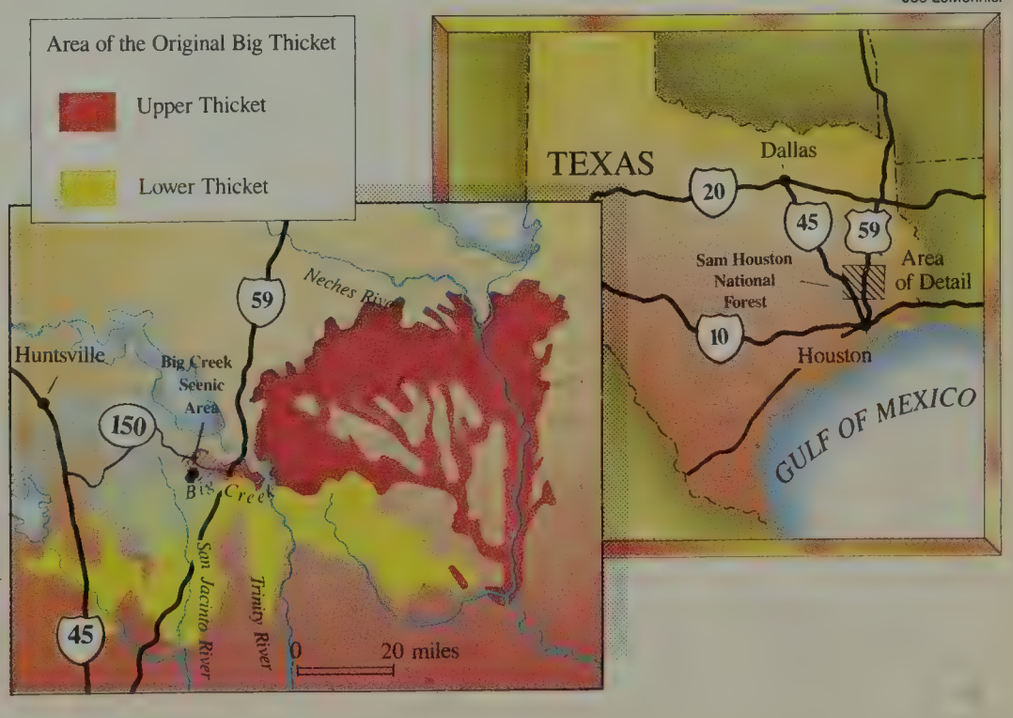
The Big Thicket occupies a gigantic sin, which slopes from north to south d consists of low hills, spring-fed eams, and flat, swampy terrain. Biolo-t Claude McLeod, who has studied the g Thicket for many years, divides the gion into the Upper Thicket and Lower icket on the basis of topography, soil pes, and dominant trees. The terrain of the Upper Thicket, in the northern part of the basin, consists of low hills dissected by clear, sparkling streams. Underlying layers of limestone have made the sandy soil less acidic than that of the Lower Thicket. The latter, which extends nearly to the gulf coast, is flat and pocked with swamps and bayous.

The thicket's vegetation is distinctive. Loblolly pine dominates the tree canopy, along with white oak, southern magnolia, and majestic, smooth-barked American beech. In the Lower Thicket the American beech is replaced by swamp chestnut oak, a tree more tolerant of acidic soils. All of these trees grow to immense size because the well-aerated soil holds considerable moisture and abounds with bacteria and fungi that decompose plant and animal residues. Diverse plants such as mesquite and bald cypress, Spanish moss and pitcher plants, as well as animals such as alligators and road runners, add to the natural attractions of the region.

The Big Thicket may be sampled within Sam Houston National Forest, where 1,130 acres have been designated the Big Creek Scenic Area, named for a clear stream that empties into the Trinity River. Several trails lead from a parking lot accessible by a forest road off State Route 150. The four characteristic species of the Upper Thicket—loblolly pine, southern magnolia, white oak, and American beech—are common along Big Creek, some attaining giant stature. Tree species beneath the canopy include sugar maple, white ash, and basswood. The dense shrub layer, which gives the Big Thicket its name, is crowded with red bay, sweetleaf, maple-leaved viburnum, strawberry bush, cat briers, and the magenta-fruited American beauty-berry. Wildflowers carpet the forest floor during the spring, led by bloodroots, trout lilies, May apples, jack-in-the-pulpits, wake-robins, and even several kinds of wild orchids.

Low, sandy hills adjacent to Big Creek provide a drier and more open habitat for post oak, blackjack oak, sassafras, winged

Joe LeMonnier



g Creek Scenic Area, Big Thicket

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d Muench

Robert H. Mohlenbrock

The fruit of the strawberry bush

sumac, black hickory, and farkleberry. Prickly pear cactus and yucca grow sporadically beneath these scrubby trees.

The plant and animal life of the Big Thicket, a mixture of elements from the northern forests, the southern coastal plain, the northeastern mountains, and the western plains, led one writer to refer to the area as the "biological crossroads of North America." In 1967 a National Park Service study of the Big Thicket identified "forest elements common to the Florida Everglades, the Okefenokee Swamp, the Appalachian region, the Piedmont forests, and the large, open woodlands of the coastal plain. Some large areas resemble tropical jungles in the Mexican states of Tamaulipas and Veracruz."

Biologists have long speculated about the origins of the Big Thicket and the diversity of its flora. Harris B. Parks suggested that the Big Thicket was at one time the bottom of a sea that extended inland from the Gulf of Mexico. As ocean levels repeatedly rose and fell during the last Ice Age, the advancing and retreating water from the gulf deposited sands in the large basin. The low-lying hills we see today are ancient sand dunes, while the lower areas toward the gulf represent prehistoric sand flats. Existing swamps and bogs are relict ponds that were trapped by dunes as the ancient seas finally subsided. Subsequent action by wind and water has molded the thicket into its current configuration.

As the last of the seas retreated, plants sprouted from seeds and other pieces of vegetation that had been deposited by the precursors of the region's present-day rivers. Extensive floodings of the Mississippi River carried in species from farther north, while warm gulf waters deposited a variety of subtropical plants. Westerly winds sowed seeds from the Plains, and other plants colonized the basin in the course of gradually expanding their ranges. Donovan Correll, the late authority on Texas plants, traced the origin of some Big Thicket plants to the Appalachians, noting that at the western edge of their range, these plants tended to differ from their eastern relatives.

Today only a portion of the once vast thicket survives. Despite protection by the National Park Service and the U.S. Forest Service, even this remnant is threatened. The southern pine beetle, which spreads a fungus, is making deep inroads into t native pine populations, destroying pin and forcing foresters to cut down diseas trees in an effort to contain the damag Ironically, efforts to control fire in sou ern forests are probably responsible f the pine beetle invasion. This plague is ju another in a series of events that has de mated the Big Woods that the Tonkaw Kanankawas, and Caddos knew and a preciated.

"This Land" highlights the biologic phenomena of the 153 U.S. national fo ests. Robert H. Mohlenbrock is dist guished professor of botany at Southe Illinois University at Carbondale.

Jim Bones

Magnolia and beech trees: American beech typifies the Upper Thicket.

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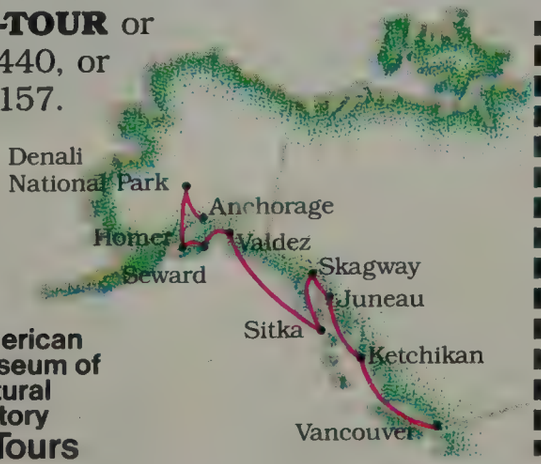

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The Good Seed

Amaranth, the high protein plant of the Aztecs, has much to recommend it today

by Raymond Sokolov

Over the years this column has provoked its fair share of angry mail. But tempers flared as never before this winter in response to a piece on bean curd (December 1985). Tofu converts around the country took umbrage and ran with it. My mistake, my sin, my greatest error was to doubt that eating tofu is utopia.

As I recall this shameful episode, I made a fair case for *Glycine max* as a splendid food plant; I endorsed bean curd as a fine thing to eat; I reported on my own clumsy but eventually successful efforts to make tofu at home. But then I blew it. Tofu is decent, agronomically sensible fare, I said, but an ideal agriculture would do better and more for people. It would give them what they are used to and what they want. And that means porterhouse steak or yak butter or *foie gras*.

Well, you can't imagine how this riled the nation's tofulators. After all these years, they wrote, you have let us down. You have burped high-cholesterol, top-of-the-food-chain gas in the faces of starving children in the Sahel. You insist on your right to get stuffed on steak. You are an insensitive, dollar-waving carnivore.

And so I am, if pious vegetarianism is the only recourse for people in this country, the only proper way for us to respect the environment, to purge ourselves of calorie guilt, and to rid the world of hunger and starvation. I share these goals with every tofumaniac and fruitarian. But I do not think that the route to attaining them runs exclusively through bean fields or depends on mortification of the flesh.

Years ago, the most articulate of vegetarians, George Bernard Shaw, said (and I paraphrase): The object of socialism is not to make everybody poor, but to make everybody rich. On the comestible level, this is my creed: An ideal agriculture gives everyone the foods he or she associates with happiness and health.

This ideal is obviously not at hand, but I think it is within our grasp. Scientists and politicians and farmers and distributors and people cooking at home all have their work cut out for them. But it is childish to rant at people who are well fed and blame their appetites for the malnutrition of others. This is simplistic, on an intellectual par with Yale students giving up meat on Tuesdays to aid their brothers and sisters in the Third World or with rock stars sending grain to Ethiopia when the government lacks the transport and the will to move food to people it controls through a policy of starvation.

We are far from realizing anybody's gastronomic utopia, but it doesn't help to juxtapose full plates on Park Avenue and empty begging bowls in Calcutta or to campaign for dietary changes here that make sense only in places where privation is the rule. And yet for years my mail has been full of letters urging me to jump on the amaranth bandwagon.

Perhaps you have not yet heard of amaranth, a broad-leafed plant that once provided the Aztecs and Incas with high-protein "cereal" seeds and greens. Apparently, because of its association with Aztec rituals of human sacrifice, amaranth was suppressed by the Spanish conquistadors. But it spread around the world and established small footholds in the Himalayas and elsewhere. Today amaranth is the object of intensive research, and it has much to recommend it.

I have been learning about the virtues of the genus *Amaranthus* in a booklet (*Amaranth, Modern Prospects for an Ancient Crop*) first published in 1984 as a report of an ad hoc panel of the Advisory Committee on Technology Innovation (ACTI), Board on Science and Technology for International Development (BOSTID), Office of International Affairs, National Research Council and recently reissued by Rodale Press. This report, aimed at "agencies engaged in development assistance and food relief officials and institutions concerned with agriculture in developing countries, and scientific communities with relevant interests," gives an overview of the literature on amaranth, as well as an account of the practical research under way at Rodale headquarters in Emmaus, Pennsylvania on ways to adapt amaranth to mechanized modern agriculture. ACTI has issued six

David Hiser; Aspen

A field of amaranth near Mexico City

studies of tropical legumes, the ged bean, aquatic weeds, and other lerexploited plants of interest to plan- s confronting the food problems of the eloping countries. With amaranth, TI seems to have bet on a winner.

Three species of *Amaranthus* produce y edible seeds about the size of mustard ds. Colorful seed heads, sometimes l over a foot in length, can yield more than 50,000 seeds with a protein content of 16 percent. This surpasses the protein content of wheat (12 to 14 percent), rice (7 to 10 percent), and corn (9 to 10 percent). What is more, the amino acid balance of amaranth seeds is heavy on lysine and can therefore be used to balance the lysine deficiency in other grain sources of protein. Like other grains, amaranth can be parched, boiled into porridge, and ground into flour. It is, however, essentially without gluten and won't rise in a yeast dough, unless wheat is added. But it does lend itself to flatbreads, and in India, it is popped like corn and mixed with honey to make a sort of candy. The greens are also an excellent protein source as long as they are boiled to remove the large quantity of nitrates and oxalic acid.

Amaranth is also a good plant for mar-

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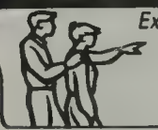

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David Hiser; Aspen

Mexicans making "allegria" candy from amaranth.

ginal growing areas. Grain amaranths thrive in virtual deserts. Vegetable amaranths survive Africa's rainy seasons. They grow like weeds. In fact, one species, *A. retroflexus,* or pigweed, is, the report says, "one of the world's worst weeds." Pigweed sends down a long taproot; its seeds germinate for at least forty years. The cultivated species are not so feisty, but the report does worry about amaranths turning into pest plants.

Myself, I am confident that the folks at Rodale and ACTI and BOSTID will guard the world against an invasion of weed amaranths. I also believe that their research will, if continued, produce uniform plants that can be harvested by machine and that will yield amounts of seed per acre competitive with wheat and corn. But will amaranth's brilliant seed heads flutter over large portions of the world's arable land? Will people accustomed to surviving on rice or corn or millet, accustomed to the special taste, feel, and handling of those grains, switch, without political duress or even with it, to an exotic grain that even the Aztecs abandoned without much fuss?

Nutritional jawboning will not sway most farmers or consumers. Amaranth will have to make it in the marketplace, competing with established grains in price, ease of production, and perhaps most importantly, in esthetic appeal. As the report acknowledges, establishing a mass market for a new staple is an enormous and lengthy undertaking. But they point to peanuts and soybeans as proof that such revolutions of taste and production are possible. Peanuts were once dismissed as pig food; now they are a major crop in the world. Soybeans, an even bigger crop, were very recently introduced this country. But once tasted, peanuts a incontestably delicious, gobbled up ever where from Beijing to Dakar. Soybean on the other hand, have sneaked their w to success in the form of a usually anon mous oil. Soy as such has not won ne friends among non-Asians except margi ally, as a "foreign" food or a health foo

At this point, with only a handful American farmers producing amarant too little is known about its potential us to say how it will fare in the real world, and when it can be grown economical There is no reason to believe that it w outperform soybeans as a source of edib oil. Its greens appear to duplicate, more less, the virtues of other potherbs such spinach. It does appear, though, even no that if amaranth is to seize more than small geographical niche in places idea suited to its growth, it will have to displa other grains. And this will happen only people want to eat it.

With some difficulty, I located gra amaranth at a large health food store Manhattan. It bore the Arrowhead Mi label and cost $3.10 a pound (8 servings) boiled the minute seeds to make a p ridge. The result was pasty and tasted, me, faintly like grass, but not aggressive so. I concluded that I would eat amaran porridge without complaint if I had no ing else, but that I would vastly pref oatmeal. Perhaps in time, if I ate am ranth every day, I would acquire a tas for this new food, just as a child will lea to love rice or grits. But who will risk t millions of dollars required to find out large numbers of people will stick w this grain long enough to like it? In seve language areas, an antiamaranth bias

y exists; people use the idiom, "Not h an amaranth."

oponents of amaranth point to several of the world where the plant has won ordinary people. North India is cer- y one. And in parts of the tropics, a Department of Agriculture bulletin ed in the ACTI report states that am- ths "can produce delectable spin- ke greens in five weeks or less, can nue to produce a crop of edible leaves ly for up to six months, and will then thousands of seeds to guarantee their val. In favorable locations they can ed themselves automatically and thus nue to produce a useful crop almost out attention."

ertainly in the American market, am- th is an extreme long shot as a crop. stigma of its relation to pigweed will acceptance in some quarters. More rtantly, cheap protein sources a- d. And there are plenty of worthwhile s and greens we already know how to and already like. The problem in this try is to keep minor traditional grains oduction: buckwheat, for example (it n't pack the protein wallop of ama- , but it makes terrific kasha).

n the other hand, the nutritional nise of amaranth is so great that, if arch turns up viable varieties, it just nt make a useful animal feed, possibly ring the price of steak.

mond Sokolov is a writer whose spe- interests are the history and prepara- of food.

Amaranth Porridge

cup amaranth seeds
teaspoon salt

Combine amaranth and salt with 3 cups water in a medium saucepan. Bring to a boil, covered. Reduce heat and let porridge simmer for 25 min- utes, or until thick.

Yield: 3 to 4 servings

Arrowhead Mills Amaranth Salad Dressing

cup oil
cup toasted amaranth seed
tablespoons tamari (sold in health food stores)
cloves garlic, minced

Combine all ingredients in a small jar. Seal the jar and refrigerate overnight so that flavors blend. Bring to room temperature before using.

Yield: About 1½ cups dressing

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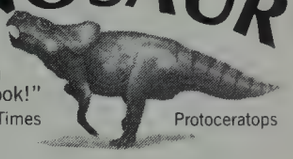

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In Cold Blood

One dank April night, photographer D. Wilder set up camp near a freshwater marsh in California's Santa Lucia Mountains, south of the Monterey Peninsula. When the moon rose, Wilder ventured out with a headlamp and camera to catch male Pacific tree frogs in their spring songfest and mating rite. Like all of their tribe, these ¼- to 1¾-inch-long amphibians, the smallest of West Coast frogs, are avid insectivores; but the preoccupied individual just a foot away from Wilder (who was flat on her stomach in the seepage) was indifferent to the gorging mosquito on its crown.

As a photographer, Wilder seized the opportunity for a "man bites dog" story, but as an entomologist she was less than surprised by the feeding behavior she was witnessing. Some mosquitoes are specialists, feeding preferentially on mammals, birds, snakes, or even on other insects. The full-bellied female mosquito atop Wilder's frog is a member of *Culex apicalis,* a species that dines on amphibians. Like her sisters (male mosquitoes don't ingest blood), she is armed with efficient mouthparts, which allow her to puncture her host's skin and to suck blood, which supplies the protein needed for her eggs to develop. On this night, the sated insect flew off, and the frog continued to sing for a mate. By summer, the replenished marsh would teem with their spawn—newcomers to the feast. —*J.R.*

Photograph by D. Wilder

In 1981, **Carol Cunningham** (page 32) was attending school when she heard of the wild horse research project in Nevada, and she quickly signed on to do fieldwork. Cunningham, who is currently studying art and literature at the University of Nevada at Reno, has done ecological monitoring in Mexico and research on bison in South Dakota. As coauthor **Joel Berger** explained, "Horses provided the opportunity to ask some basic biological questions and find answers that appeal to scientists interested in theory and applied biology." Berger, an associate professor of wildlife ecology at the University of Nevada at Reno and a research associate with the Smithsonian Institution's Conservation and Research Center, has recently published the results of the study in *Wild Horses of the Great Basin* (University of Chicago Press, Chicago, 1986). While Berger's time is mainly taken up with horses, he has studied bison and bighorn sheep and would like to continue working with mammals in desert, montane, and savanna ecosystems.

For the past fourteen years, **John Alcock** (page 74), a professor of zoology at Arizona State University, has lived in the Sonoran Desert. Alcock's main interest is insect mating systems. In addition to blister beetles, which he explores in this issue, his projects include the study of territoriality in certain bees and dragonflies, nectar-feeding behavior in wasp pairs, and the mating of moths that carry castanetlike knobs on their wings. An enthusiastic field biologist, Alcock says, "As a holdover from the nineteenth century, I am continually grateful to find employment that permits, even insists, that I enjoy myself." Accordingly, he recommends for further reading *The Pleasures of Entomology*, by Howard E. Evans (Smithsonian Institution, Washington, D. C., 1985). Alcock's own *Sonoran Desert Spring* (University of Chicago Press, Chicago, 1985) touches on blister beetle biology as well as other facets of desert life.

For **D. Wilder**, (page 106) entomology was a calling. "Born to be an entomologist," she claims that she "never considered being or desired to be anything else." For a specialty, Wilder zeroed in on the order Diptera (which includes mosquitoes). A former researcher with the U.S. Department of Agriculture and at present a research associate with the California Academy of Sciences, Wilder has for the past three years also managed a full-time career as a nature photographer, spending two-thirds of her time in the field. Using a Nikon FM2 with extension tubes and Vivitar flash, Wilder captured the duo for this month's "The Natural Moment" on Kodachrome 25 film. (Her work can also be seen on pages 75 and 77 of this issue.) Wilder's favorite diversion—growing vegetables—is one that she says offers "economy of effort," being "great for cooking and for photographing insect pests." For readers wishing to delve into the natural history of mosquitoes, she recommends Marston Bates's *The Natural History of Mosquitoes* (Harper & Row, New York, 1965) and *Mosquitoes*, by J.D. Gillett (Weidenfeld and Nicolson, London, 1971).

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NATURAL HISTORY

Vol. 95, No. 5, May 1986
American Museum of Natural History, New York, N.Y.
Robert G. Goelet, President
Thomas D. Nicholson, Director
L. Thomas Kelly, Assistant Director

4 Letters

6 Wolves Across the Border *Jim Robbins*
Gone for half a century, wolves have finally returned to the northwestern United States. Will we let them stay this time?

18 This View of Life *Stephen Jay Gould*
Knight Takes Bishop?

36 Daughters of the Forest *Agnes Estioko-Griffin*
A man may hunt from sun to sun, and so may a woman in one Philippine tribe.

44 Riders in the Sea *Photographs and text by Lovell and Libby Langstroth*
The hooked slipper snail prefers hitchhiking to walking.

60 Fossil Windfall at Antarctica's Edge *William J. Zinsmeister*
A tiny island has produced some answers to big paleontological questions.

68 Sex and Gluttony on Delaware Bay *J. P. Myers*
Each spring—in an age-old ritual—horseshoe crabs re-create and shorebirds refuel.

78 The Natural History of AIDS *Matthew Allen Gonda*
Why did the deadly virus emerge so suddenly, and where did it come from?

82 Celestial Events *Thomas D. Nicholson*
Three Planets Strut Their Stuff

86 Reviews *Colin Beer*
Words and Chimps

90 This Land *Robert H. Mohlenbrock*
Pink Cliffs, Utah

96 At the American Museum

98 A Matter of Taste *Raymond Sokolov*
Chowder Chauvinism

102 The Natural Moment *Photograph by Mark Newman*
Catch of the Day

104 Authors

Cover: *A timber wolf pauses at the edge of a forest in Alberta, Canada. Late last fall, a pack of wolves entered the northwestern United States from Canada. Story on page 6. Photograph by Stephen J. Krasemann; DRK Photo.*

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Letters

Running Commentary

Drs. Wassersug seem to have slipped beyond a kindly attempt to correct fallacies about the benefits of fitness ("Fitness Fallacies," March 1986). Am I mistaken or do I detect an underlying agenda to discredit fitness as a desirable goal? This article employs a number of distortions and dubious techniques hardly worthy of *Natural History*.

As a family physician and admitted fitness freak, I've kept close tabs on the medical literature in this area. I think the authors are not accurately reflecting the best available information. For instance, the hourly death rate while jogging may be seven times that of a sedentary activity but what does that prove? In fact, there is evidence that the mortality rate, at least from heart disease, is lower for runners.

Trotting out the examples of James Fixx and John B. Kelly only heightens my suspicions. No one but the most ardent apologist for couch potatoism could extract any significance from those two anecdotes. The authors must know that. They also must know the difference between exercise-induced tachycardia and a pathologic cardiac tachyarrhythmia but seem to be doing their best to confuse the two in order to scare someone.

With respect to the longevity issue, I doubt whether the average fitness type is as concerned with that as with "long activity," that is, keeping active well into later years. The lack of a medical study is easy to explain if you consider the fitness craze to have started in the 1970s—or even the 1960s. It will be another fifty or sixty years before the numbers for large homogeneous groups are known. But isn't it odd that cardiovascular mortality is dropping and life expectancy increasing? It may not be because of increased fitness, but exercise doesn't seem to be as catastrophic as the authors seem to be implying.

The Wassersugs' certainty that many are confusing evolutionary fitness with physical fitness seems pretty far-fetched to me. What seems flat wrong is the concept that an unconscious wish could steer people toward a maladaptive behavior, at least in any numbers. If such a thing were possible, would *Homo sapiens* be as successful? On the other hand, a conscious wish to be more attractive to the opposite sex seems entirely plausible, for to have reproductive success, you first need opportunity.

MICHAEL E. CALLAHAN, D.O.
Galeton, Pennsylvania

In "Fitness Fallacies" Joseph and Richard Wassersug make the statement that "there is no evidence that running five miles a day, for instance, improves life expectancy or even appreciably enhances health . . . ." It seems to this reader that such an assertion is quite incorrect. Dr. Paffenbarger suggests that exercise equivalent to four to six hours a week of jogging is optimal. Unless there is some coincidence, the Paffenbarger study of 17,000 Harvard University graduates referred to in the article is the same one on which this conclusion is based.

Five miles in an hour is a twelve-minute mile, quite slow and comfortable, and below what most runners aspire to. That works out to five miles a day, four to six times a week, on the basis of a twelve-minute mile. (My friends and I, ranging from forty-two to fifty-two years of age, from slim to chubby, from smoking to not smoking, from healthy to colitis, average an eight-minute, thirty-second mile with no problems, talking all the while.)

I cannot possibly imagine how one might translate four to six hours a week into the "brief bouts" of three to five minutes mentioned by the Wassersugs. That would be seventy-one to eighty sessions per week. That is a lot of showers.

RICHARD S. MITNICK
Highland Park, New Jersey

Wyoming's Ferrets

In "Decline and Fall of the Black-footed Ferret" (February 1986), David Weinberg is unjustifiably hard on the Wyoming Game and Fish Department in particular and the state of Wyoming in general. I finished Weinberg's article with the impression that if the state and the Game and Fish Department had just turned the ferret project over to Biota Research and Consulting, the population would no longer be in danger of extinction.

A basic premise of population ecology is cycles. The increase in the ferret population since it was discovered in 1981 is part of a population cycle. Plague and distemper outbreaks are also cyclic; the plague outbreak in the prairie dog population led to a decline in the ferrets' main food source. This decrease in food probably increased the ferrets' susceptibility to the distemper virus, which was probably present in the area all the time. That some of the animals have survived past the distemper incubation period reinforces the natural-cycle theory and shows that the ferrets can, and probably in the past did, survive distemper outbreaks without intervention by trapping and vaccination.

I wish all the people on the project well, but I have to wonder if the Biota Research and Consulting people could have saved the woolly mammoth or saber-toothed tiger from the Ice Age.

PAT GOODSON
Sundance, Wyoming

A Tough Nut

In "A Tree of Life Grows in Brazil," (December 1985), the authors state: "One reason the babassu palm does so well there is that its fruit has a two-inch-thick husk. It takes five and one-half tons of force to break one open; no mammal currently in Maranhão (or anywhere else in the American tropics) has that kind of strength." But on page 43 they write, "Hunters use the leaves to make blinds when they are after agoutis, pacas, and porcupines, all of which feed on babassu fruit." There appears to be a contradiction, which I am sure can be easily clarified.

KEVIN COOKE
Berkeley, California

Anthony Anderson replies:

Contemporary mammals feed exclusively on the starchy mesocarp of the babassu fruits, which surrounds the inner fruit wall, or endocarp. It is this inner wall that is extremely hard to break and protects the seeds contained within. The design of babassu fruits thus provides sustenance for mammals (many of which are dispersal agents) while protecting seeds against potential predators. □

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Wolves Across the Border

The reappearance of an endangered predator in Glacier National Park may be greeted with howls of protest

by Jim Robbins

After thirteen puzzling years of trying to answer one question about wolves, biologist Robert Ream's luck has changed. He now has one answer and, in typical scientific fashion, a whole list of new questions.

The original question was, Why didn't wolves cross the border between Canada and western United States, particularly in the protected wilds of Montana's Glacier National Park? The region contains large herds of deer, elk, and moose—favorite prey of the wolf. A half century ago and earlier, wolves lived there successfully, and ecological conditions had not changed significantly since then. Why, then, did the wolves stay away?

The question was answered unexpectedly last November when a pack of twelve wolves—named the Magic Pack—moved south from Alberta to Glacier National Park. It was the first pack to take up residence in the western United States since the 1930s (some 1,200 wolves inhabit parts of Minnesota, northern Wisconsin, and Michigan). There is also a pair of wolves roaming the east side of the park, and a lone male on the west side.

The wolves appear to have settled into their new habitat. They are making regular kills and are eating well. At least one pair, perhaps two, are expected to den this spring, and biologists believe the inchoate population may double.

Now Ream is confronted with a host of new questions: Will the pack grow and divide? And what, after a fifty-year absence, will be the effect of wolves on the ecosystem? "The western national parks have been without major predators for a long time. They have an abundance of ungulates—moose, elk, white-tailed and mule deer. We're going to find out just what impact the wolf has on those animals," Ream notes.

Clifford Martinka, supervisory biologist at Glacier National Park for nineteen years, says, "In reviewing the history of the park, I think this is the biggest thing that has happened here since the creation of the park itself."

As the wolf and its prey adjust to each other, there may be, Martinka adds, some ecological chaos among wildlife in the park, for the wolf as a predator can have profound effects on population levels in the short term and on the evolution of some species in the long term.

He is also concerned about the effects the wolf, protected as an endangered species, might have on other species that inhabit a precarious niche in the Glacier ecosystem. Will the wolves outcompet the grizzly bear, their fellow predator, fo carrion, a small, but vital portion of th bear's diet? And is there a risk for a smal endangered population of mountain car bou—perhaps as few as twenty or twenty five—which spends a part of the year i northern Idaho and possibly in northwes ern Montana near Glacier Park?

The wolf's reappearance has also begu to fan back to life the long-dead embers o human controversy. The economies o Montana and Idaho are based largely o

Should predators be protected?

Wolfgang Bayer; Bruce Coleman,

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agricultural and resource industries. The presence of the wolf could throw an unexpected wrench into the currently troubled, sputtering operation of these industries. To make matters worse, the wolf appears on the scene in the midst of a vitriolic debate between ranchers and state governments over management of another predator—the grizzly bear.

Compounding the problem, according to U.S. Fish and Wildlife Service wolf recovery team members, is a flaw in the Endangered Species Act. Under the act, no wolf—even individuals that kill livestock—can be killed. This has led the director of Montana's Department of Fish, Wildlife and Parks to bow his agency completely out of wolf recovery until the control problem is solved.

So far, few hunters in Montana have complained about the wolf. But near the Boundary Waters Canoe Area in northern Minnesota, the loudest outcry against the wolf has been from hunters who see the wolves as competition.

Biologists are also concerned about the impact of the public on the wolves. Already some people who live near Glacier National Park have been searching out the wolf pack, to view the animals or howl with them. How will the wolves do in the summer when the park fills up with tourists and their boats, tents, and cars?

Historically, the Rockies had been prime country for *Canis lupus irremotus,* one of the world's twenty-three subspecies of the gray wolf. But toward the end of the nineteenth century, events and people drove the wolf out of the region.

In the mid-1870s millions of bison still wandered the Great Plains, providing a critical food source for wolves, grizzlies, and Native Americans. A decade and a tidal wave of slaughter later, only a few hundred bison remained in the hidden valleys of Yellowstone National Park. At the same time, entrepreneurs from around the country—drawn by the opportunity to cash in on millions of acres of free grass—imported domestic cattle and sheep to replace the buffalo. The livestock industry found the living easy for the first few years, simply turning the animals out onto the open range. But the brutal winter of 1886 and 1887, a legendary season that wiped out 95 percent of some herds, forced livestock operators to retrench. Fences went up and so did the cost of operation. Livestock losses became a critical factor for outfits operating on a low profit margin.

Deprived of the bison, the wolf turned to the plentiful and vulnerable cattle and sheep. A bounty was placed on the head of the wolf, and between 1883 and 1918 more than 80,000 wolves were killed in Montana alone—either poisoned, shot, or dynamited in their dens. The wolf was pursued with a vengeance, and even though its numbers had been greatly reduced by the century's turn, ranchers were not appeased. The wolf had become a whipping boy, it seems, for the difficulties of life on the frontier. The pogrom expanded to bizarre proportions when, in 1905, the Montana state legislature passed a law requiring the state veterinarian to inoculate wolves with a disease called sarcoptic mange and release them back into the wild where they could infect other wolves. The program was a failure that eventually turned into a disaster when a similar disease spread to livestock. But that did not dampen the enthusiasm for wiping out the wolf, and the campaign continued. In the 1930s, even though the wolf population had been nearly decimated, government trappers came along to provide the quietus. They hunted, clubbed, and trapped the wolf to extinction in the Rockies.

Cattle ranchers were not alone in their hatred of wolves; it was an almost universal belief, held even by the National Park Service, that the wolf deserved to be obliterated because it was evil and preyed on species valued by man. In 1917, for example, the acting superintendent of Yellowstone, Charles A. Lindsley, wrote in his monthly report: "Timber wolves were reported from several different sources during the month, and while not numerous, they are a menace to other animals as they kill often. Two were killed during the month of December by Steve Elkins, who is working by day with his trained dogs, hunting mountain lions."

The treatment of the wolf in the West was similar to what it received throughout its range, which included most areas around the globe north of thirty degrees latitude. It was exterminated in Europe, with the exception of small populations in northern Spain and Italy, Germany, and Eastern Europe. India and the Near and Middle East still have some wolves, and Russia has a large population. The number of wolves in China is unknown. Japan's wolves are gone. Canada and Alaska have large populations of wolves, perhaps totaling more than 25,000.

The red wolf, a separate species that at one time roamed throughout the southeast United States, is all but gone, with a population of perhaps 100 left in the swamps and thickets of southeastern Texas and southwestern Louisiana. Biologists fear a loss of the remaining red wolves because of interbreeding with coyotes.

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Mountain wolf received endangered status—Ream began to compile sightings of wolves, some of which he believed to be spurious—coyotes or dogs mistaken for wolves. Still, reliable sightings continued, many from the border region, and Ream and his students scoured the North Fork of the Flathead River, on the west side of the park. Even though breeding populations had vanished, lone wolves were sighted occasionally in Montana. Human howling comes in handy for this kind of survey, for wolves usually return even a rough approximation of a howl. For several years, however, the howls of researchers went unanswered.

Then in 1979, Joe Smith, who was working for Ream, trapped and radio-collared a lone female wolf near Kishnena Creek, a remote drainage in the extreme northwestern corner of the park. Kishnena, as she was called, apparently then took up and mated with a black wolf that had only three toes on one foot. They denned in Canada, a rifle shot from the border, and produced a litter of seven pups in 1982. Kishnena and the black wolf were thought to be dispersers from Banff National Park in the Canadian Rockies, some 150 miles to the north. The structure of a wolf pack is such that only a single dominant male and female will mate, while the rest of the animals assume a subordinate role and do not reproduce. Disperser wolves strike out on their own, pioneer new territory, and often start a new pack.

Kishnena's seven pups at first took up residency in British Columbia, and were probably the progenitors of the Magic Pack, so named because it seemed to be impossible to locate. Those seven had a second generation of pups in 1984, then a third in 1985, bringing the total to b tween fifteen and twenty. Last fall hov ever, perhaps because of large-scale lo ging, oil exploration, and hunting Canada, where wolves are not a protecte species, the Magic Pack moved down in the 1,600-square-mile park.

The migration of wolves into Glaci National Park is considered a natural r covery. In recent years a great deal attention has been focused on the pr posed reintroduction of the wolf into Ye lowstone National Park—a prime locatio for wolves because it covers almost 3,5 square miles and has an extremely lar population of ungulates. However, the i sue is a political tar baby for a number reasons—first, reintroduction means tra ping wolves where populations are healt and importing them to the park. Secon the park is surrounded by sheep and catt allotments on national forest land, a many of the ranchers there are alread angry about existing problems with fede ally protected grizzly bears, which occ sionally satisfy a craving for livestock. Glacier National Park there is only o large cattle operation, on the west side the park, which makes the recovery the more palatable to cattlemen. The politic problems with the wolf around Yello stone are so great that Ream, who is on t U.S. Fish and Wildlife Service Northe Rocky Mountain Wolf Recovery Tea voted against recommending wolf reintr duction there.

But John Weaver, a Forest Service ologist who is on the Northern Roc Mountain Wolf Recovery Team, sa wolves may be introduced there with two to five years. "It's got the best pote tial of any of the three areas proposed f recovery," he said, "because of it's t

Canadian gray wolf pups emerge from their den. Wolfgang Bayer; Bruce Coleman,

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mendous prey base, including ungulates that winter in the park."

The U.S. Fish and Wildlife Service recovery plan for the northern Rocky Mountain wolf calls for a return of the animal to three areas—Glacier, Yellowstone, and the Frank Church/River-of-No-Return Wilderness Area in central Idaho—before it will be taken off the endangered species list. A recovered population, according to the plan, is ten pairs of breeding wolves for each region, which, if the average pack is five, including one mating pair in each pack, means a total of about 150 wolves in the Rockies.

Zone management was pioneered as a tool to manage the Minnesota and Wisconsin wolf populations and is predicated on the premise that some parts of the wolf's original range, such as agricultural areas, are now undesirable. The wolf recovery plan divides habitat into three categories. Zone one is an area of 3,000 contiguous square miles, with an excellent prey base, with less than 10 percent private land, and less than 20 percent subject to livestock grazing—a sanctuary like Glacier National Park and the adjacent wildlands. Zone one wolves are fully protected, and management activities are subordinate to the wolf. Zone two is a buffer zone, a remote public land with good wolf potential, which surrounds a zone one. Problem animals could be trapped and moved by a government agent. Zone three has poor recovery potential and possibly substantial conflict. Offending wolves would be removed from these areas.

Livestock operators are not thrilled about the return of an old nemesis, natural or otherwise. Even with a zone system, the industry expects problems. "They don't understand boundaries, they don't understand zones," said Stuart Doggett of the Montana Stockgrowers Association. "You may talk about zone three, but it's not as if you can tell Mr. Wolf, 'Here's your boundary, please don't go any farther, we have cattle here.' He doesn't respect or understand that."

Livestock interests think the wolf should be downlisted from an endangered to a threatened species to allow for more flexible management. "If the wolf was not on the endangered species list, I think we could protect ourselves," said Mons Teigen, director of the Montana Stockgrowers Association, a group that was formed a century ago around the nucleus of perceived wolf predation. "[The wolf] being on the list, we have to defend ourselves with our hands tied behind our backs." Asked if he thinks wolf and livestock can coexist, Teigen shook his head and replied, "I doubt it." Teigen believes labyrinthine federal endangered species regulations may lead a few ranchers to control wolves with the three-S method. "Shoot, shovel, and shut up," he said. "Maybe that system has something to offer—I don't know."

As the law reads now, the Fish and Wildlife Service has the authority to trap livestock-killing wolves, but only to relocate them. Destruction is against the law. And moving the animals, says Bart O'Gara, leader of the recovery team, is next to impossible because no one will accept a livestock-killing wolf. Both he and Bob Ream think a change in the Endangered Species Act to allow greater flexibility with endangered predators is vital to wolf recovery. "Managing an endangered predator is quite different from managing an endangered butterfly," O'Gara said. "If I was a rancher I'd be worried."

In Minnesota the problem was eased by downlisting the wolf from an endangered to a threatened species, a move that allows wolves to be destroyed. Ream says that such a move in the Rockies would be a

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ave error. "Downlisting at this time ould be challenged because we only have teen or twenty wolves. Philosophically, d biologically, downlisting doesn't ake sense, and I would be opposed."

While a zone concept attempts to ad-ess the concern of livestock operators, tle can be done to assuage hunters. In innesota some hunters formed a vocal tiwolf group and even issued bumper ckers that read "Preserve Our Deer—noot a Wolf." In Montana some resi-nts of the North Fork of the Flathead iver have expressed concern over preda-on on ungulate populations, but hunters the area are not yet concerned. On the ntrary, Jim Richard, a board member d former executive director of the Mon-na Wildlife Federation, a sportsmen's oup, said the organization welcomes the turn of the predator. "We passed a reso-tion supporting wolf recovery," Richard id. "We think the wolf will provide for tural, healthy populations. Big game nting will be improved. I don't think e'll have to shorten or curtail hunting ason for lack of game."

Wolf biologist L. David Mech has ar-ued that wolves do not compete with mans for game animals, largely be-use wolves are not the primary limiting factor of game populations. Bad weather and lack of forage exact the highest mortality, and wolves take the animals that would die of these causes. "With the small numbers in the park there will be essentially no impact," Mech said.

Recent research in Alaska and Canada, however, indicates that once wolves take firm hold in Glacier, they could have a big impact on elk, moose, and deer populations. During the winters of 1983-84 and 1984-85, John Gunson, a carnivore-management biologist with the Alberta Fish and Wildlife Division, studied a northern Rocky Mountain wolf pack near the Blackstone River, just east of Jasper National Park in the Canadian Rockies of Alberta. The Blackstone pack, with a mean of 10 wolves, killed 145 animals per year—79 elk (including calves), 32 deer, 20 moose, 10 bighorn sheep, and 4 feral horses—roughly 14 prey animals per wolf per year. "In that particular area the elk population is declining," Gunson said. "Wolf predation is the most important limiting population factor of that herd, of all mortality factors." Hunters took about 24 bulls per year from the same population, he said.

In Alaska, according to Bob Stephenson, a wildlife biologist with the Alaska Department of Fish and Game in Fairbanks, research shows that a healthy wolf population can kill from 10 to 30 percent of an ungulate population, when at its early summer peak. Wolf predation, especially in conjunction with a hard winter, can raise the mortality rate above the rate of replacement. "We have places where the moose have virtually disappeared and they're not coming back because of wolves and grizzlies," Stephenson said.

What will happen to the Glacier Park wolves this summer when people swarm into the parks, especially the backcountry? Cliff Martinka is concerned that the pressure could drive the wolves back into Canada. "The den site and rendezvous sites [where the wolf pups wait for their parents to return with food] are very sensitive," he said. "There could be some restrictions on humans in those areas."

With the help of the radio transmitters they have placed on the Magic Pack wolves, biologists can locate the animals and follow them on foot or skis. By analyzing scats and kill sites, they can determine what the wolves are eating. Although the study is in its infancy, several things have been learned; among them, that the pack of twelve is larger than most in the Great Lakes area, where packs are composed of

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up to eight animals. Ream believes th pack will eventually split up, and individ uals may start their own packs. One of th reasons the pack is so large now, Rean said, is an abundance of food.

The animals make a kill every two t three days, taking a grown white-taile deer or the equivalent biomass in the form of a different species, such as elk. Th Rocky Mountain wolves, which are large than the eastern wolves, are also expecte to feed on beaver, snowshoe hares, ro dents, and moose, which are numerous i the area. Collecting data on kills has bee difficult. "The utilization of the carcasse has almost been more than 100 percent," said Mike Fairchild, a researcher who ha examined many of the kills. "They're eat ing all the meat and cracking bones to ge to the marrow. With a pack of twelv wolves they're engulfing almost every thing. Oftentimes we find only a fe pieces of hide and not even much skeleta remains. There have been times we'v been able to re-create the discovery of th prey and the chase and the kill, but often times not."

While studies of the wolves' range ar just beginning, a lone male, Sage, seems t be covering a great deal of ground, with a estimated home range of 2,000 squar miles. Sage is believed to be from a 198 litter, but he is definitely no longer a mem ber of the pack. The Magic Pack has home range of 500 to 600 square miles This compares with a home range of 95 square miles for the Blackstone pack o ten northern Rocky Mountain wolves i Alberta. Home ranges vary greatly amon wolves, reportedly from 36 square mile for two wolves to 5,000 square miles for pack of ten in Alaska.

The wolves are seen infrequently. I January, after locating the lone male Sag with the radio, we watched him through field glasses near an elk carcass on th park's southwestern boundary. At 10 pounds he is a large wolf, even for a male We discovered his tracks in the snow nea the elk kill; they measured four and a hal inches across and five and a half inche long. Male wolves in Minnesota averag eighty to eighty-five pounds. We watche as Sage, his pelage a mottled silver-gra and black, took note of our presence an moved away from the kill. Wary, thoug not alarmed, he loped briskly away fro the dead bull elk, eventually disappearin over a ridge.

Because the wolf's reproductive rate i relatively high—a female has from four t seven pups per year—the Glacier popula tion could grow rapidly. The estrous pe riod for the female is in February, gesta tion takes sixty days, and denning occur

April. "I think we're over the hump in
ms of wolf recovery," Ream said, cau-
usly enthusiastic. "This spring I'm pre-
ting we're going to have two or three
ns in the study area. And if each of
se two or three dens has six or seven
ps, we're going to double the population
one year. There are some 'ifs' there, but
certainly biologically possible."

The presence of wolves in Glacier has
en rise to some acute philosophical
estions at the National Park Service.
ghorn sheep herds in the Glacier region
ve been substantially reduced by hu-
n encroachment and the park popula-
n is, according to Martinka, artificially
v. Losses to the gene pool could be criti-
. "The philosophical question is," he
d, "do you want a naturally occurring
edator to be preying on a species to the
ent it causes them to become extinct?"
study on the remnant population of big-
rns in Glacier is currently under way
d should provide insight into its status.
What effect might the wolf have on two
dangered species—the woodland cari-
u and the grizzly bear—in northwestern
ontana? Only an estimated twenty-five
ribou, including five reproducing fe-
ales, inhabit northern Idaho, the south-
n edge of their boreal forest habitat.
ny loss of caribou could be critical to
covery efforts. Wolves might compete
th grizzly bears for carrion, and wolves
ay even take a grizzly cub. But most
olf experts agree that while wolves and
izzly bears do interact occasionally,
ey do not pose a threat to each other.

"We've seen that bears and wolves use
e same country," said Bob Stephenson.
There is mutual avoidance by the two
imals. In fact, it can work to the bear's
vantage if the wolves are making a lot of
lls."

Despite potential problems, Glacier
ational Park is probably the best place
r the wolf's reappearance in the West.
housands of square miles of wilderness
join the park.. And the prey that the
olves fed on during their previous occu-
tion is still there, with the exception of
ribou and bison, whose numbers were
t significant.

The big question is, Can man and wolf,
ith so troubled a relationship in the past,
exist in harmony or, at least, under an
neasy truce? Have we learned enough in
e past fifty years? The patience and un-
erstanding of those who must live near
e wolf will surely be tried.

*m Robbins, a freelance writer based in
elena, Montana, writes about the
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Knight Takes Bishop?

The facts about the great Wilberforce-Huxley debate don't always fit the legend

By Stephen Jay Gould

I have not the slightest doubt that truth possesses an inestimable moral value. In addition, as Mr. Nixon once found to his sorrow, truth represents the only way to keep a complex story straight, for it becomes impossible to remember when you told what to whom if your words have no anchor in actual occurrence.

> Oh, what a tangled web we weave,
> When first we practice to deceive!

Yet, for a scholar, there is nothing quite like falsehood. Lies are pinpoints—identifiable historical events that can be traced. Falsehoods also have motivations—points of departure for our ruminations on the human animal. Truth, on the other hand, simply happened. Its accurate report teaches us little beyond the event itself.

In this light, we should note with interest that the most famous story in all the hagiography of evolution is, if not false outright, at least grossly distorted by biased reconstruction long after the fact. I speak of Thomas Henry Huxley's legendary encounter with the bishop of Oxford, "Soapy Sam" Wilberforce, at the 1860 meeting of the British Association for the Advancement of Science, held in His Lordship's own see.

Darwin had published the *Origin of Species* in November 1859. Thus, when the British Association for the Advancement of Science met at Oxford in the summer of 1860, this greatest of all debates received its first prominent public airing. On Saturday, June 30, more than 700 people wedged themselves into the largest room of Oxford's Zoological Museum to hear what was, by all accounts, a perfectly dreadful hour-long peroration by an American academic, Dr. Draper, on the "intellectual development of Europe considered with reference to the views of Mr. Darwin." Leonard Huxley wrote, in *Life and Letters of Thomas Henry Huxley*:

> The room was crowded to suffocation . . . . The very windows by which the room was lighted down the length of its west side were packed with ladies, whose white handkerchiefs, waving and fluttering in the air at the end of the Bishop's speech, were an unforgettable factor in the acclamation of the crowd.

The throng, as Leonard Huxley notes, had not come to hear poor Dr. Draper drone on about Europe. Word had circulated widely that "Soapy Sam" Wilberforce, the silver-tongued bishop of Oxford, would attend with the avowed purpose of smashing Mr. Darwin in the discussion to follow Draper's paper.

The story of Wilberforce's oration and Huxley's rejoinder has been enshrined among the half dozen greatest legends of science—surely equal to Newton beaned by an apple or Archimedes jumping from his bath and shouting "Eureka!" through the streets of Syracuse. We have read the tale from comic book to novel to scholarly tome. We have viewed the scene, courtesy of the BBC, in our living rooms. The story has an "official version" codified by Darwin's son Francis, published in his *Life and Letters of Charles Darwin*, and expanded in Leonard Huxley's biography of his father. This reconstruction has become canonical, copied from source to later source hundreds of times, and rarely altered even by jot or tittle. Consider just one of countless retellings, chosen as an average and faithful version (From Ruth Moore's, *Charles Darwin*, Hutchinson, 1957):

> For half an hour the Bishop spoke savagely ridiculing Darwin and Huxley, and then he turned to Huxley, who sat with him on the platform. In tones icy with sarcasm he put his famous question: was it through his grandfather or his grandmother that he claimed descent from an ape? . . . At the Bishop's question, Huxley had clapped the knee of the surprised scientist beside him and whispered: "The Lord hath delivered him into mine hands" . . . .[Huxley] tore into the arguments Wilberforce had used . . . . Working himself up to his climax, he shouted that he would feel no shame in having an ape as an ancestor, but that he would be ashamed of a brilliant man who plunged into scientific questions of which he knew nothing. In effect, Huxley said that he would prefer an ape to the Bishop as an ancestor, and the crowd had no doubt of his meaning.
>
> The room dissolved into an uproar. Men jumped to their feet, shouting at this direct insult to the clergy. Lady Brewster fainted. Admiral Fitzroy, the former Captain of the Beagle, waved a Bible aloft, shouting over the tumult that it, rather than the viper he had harbored in his ship, was the true and unimpeachable authority . . . .
>
> The issue had been joined. From that hour on, the quarrel over the elemental issue that the world believed was involved, science versus religion, was to rage unabated.

We may list as the key, rarely challenged features of this official version, the following claims:

1. Wilberforce directly bearded and taunted Huxley by pointedly asking, in sarcastic ridicule, whether he claimed descent from an ape on his grandfather's or grandmother's side.

2. Huxley, before rising to the challenge, mumbled his famous mock-ecclesiastical sarcasm about the Lord's aid in his coming rhetorical victory.

3. Huxley than responded to Wilberforce's arguments in loud, clear, and forceful tones.

4. Huxley ended his speech with a devastatingly effective parry to the bishop's taunt.

5. Although Huxley said only that he would prefer an ape to a man who used skills of oratory to obfuscate rather than seek truth, many took him to mean (and some thought he had said) that he would prefer an ape to a bishop as an ancestor. (Huxley, late in life, disavowed this stronger version about apes and bishops. When Wilberforce's son included it in a biography of his father, Huxley protested and secured a revision.)

6. Huxley's riposte inspired an uproar.

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The meeting ended forthwith and in tumult.

7. Although Moore, to her credit, does not make this claim, we are usually told that Huxley had scored an unambiguous and decisive victory—a key incident in Darwin's triumph.

8. This debate focused the world's attention on the real and deep issue of Darwin's century—science versus religion. Huxley's victory was a pivotal moment in the battle for science and reason against superstition and dogma.

I have had a strong interest in this story ever since, as an assistant professor on sabbatical leave at Oxford in 1970, I occupied a dingy office in the back rooms of the Zoological Museum, now crammed with cabinets of fossils and subdivided into cubicles, but then the large and open room where Huxley and Wilberforce fell to blows. For six months, I sat next to a small brass plaque announcing that the great event had occurred on my very spot. I also felt strong discomfort about the official tale for two definite reasons. First, it is all too pat—the victor and the vanquished, good triumphing over evil, reason over superstition. So few heroic tales in the simplistic mode turn out to be true. Huxley was a brilliant orator, but why should Wilberforce have failed so miserably? Much as I dislike the man (as my last essay attests), he was no fool. He was as gifted an orator as Huxley and a dominant intellectual force among conservative Anglicans.

Second, I knew from preliminary browsings that the official tale was a reconstruction, made by Darwin's champions some quarter century after the fact. Amazingly enough (for all its later fame), no one bothered to record the event in any detail at the time itself. No stenographer was present. The two men exchanged words to be sure, but no one knows what they actually said, and the few sketchy reports of journalists and letter writers contain important gaps and contradictions. Ironically, the official version has been so widely accepted and unchallenged, not because we know its truth by copious documentation, but rather because so little data exist for a potential challenge.

For years, this topic has been about number fifty in my list of one hundred or so potential essays (sorry folks but, the Lord and editors willing, you may have me to kick around for some time to come). Yet for want of new data about my suspicions, it remained well back in my line of processing, until I received a letter last September from my friend and distinguished Darwin scholar Sam Schweber of

Brandeis University. Schweber wrote: "I came across a letter from Balfour Stewart to David Forbes commenting on the BAAS meeting he just attended at which he witnessed the Huxley-Wilberforce debate. It is probably the most accurate statement of what transpired." I read Stewart's letter and sat bolt upright with attention and smiles. Stewart wrote, describing the scene along the usual lines, thus vouching for the basic outline:

> There was an animated discussion in a large room on Saturday last at Oxford on Darwin's theory where the Bishop of Oxford and Prof. Huxley fell to blows . . . . There was one good thing I cannot help mentioning. The Bishop said he had been informed that Prof. Huxley had said he didn't care whether his grandfather was an ape [*sic* for punctuation] now he [the bishop] would not like to go to the Zoological Gardens and find his father's father or his mother's mother in some antiquated ape. To which Prof. Huxley replied that he would rather have for his grandfather an honest ape low in the scale of being than a man of exalted intellect and high attainments who used his power to pervert the truth.

Colorful, though nothing new so far. But I put an ellipsis early in the quotation, and I should now like to fill it in. Stewart wrote: "I think the Bishop had the best of it." Score one big point for my long-held suspicions. Balfour Stewart was no benighted cleric, but a distinguished scientist, Fellow of the Royal Society, and director of the Kew Observatory. Balfour Stewart also thought that Wilberforce had won the debate!

This personal discovery sent me to the books (I thank my research assistant, Ned Young, for tracking down all the sources, no mean job for so many obscure bits and pieces). We gathered all the eyewitness accounts (damned few) and found a half dozen or so modern articles, mostly by literary scholars, on aspects of the debate. (See Janet Browne in the *Journal of the Society for the Bibliography of Natural History,* vol. 8, 1978, p. 351–66; Sheridan Gilley in K. Robbins (editor), *Religion and Humanism,* Blackwell, 1981, p. 325–40; and J. R. Lucas in *The Historical Journal,* vol. 22, 1979, p. 313–30. I especially commend Browne's detective work on Francis Darwin's construction of the official version, and Gilley's incisive and well-written acount of the debate.) I confess disappointment in finding that Stewart's letter was no new discovery. Yet I remain surprised that its key value—the claim by an important scientist that Wilberforce had won—has received so little attention. So far as I know, Stewart's letter has never been quoted *in extenso,* and no reference gives it more than a passing sentence. But I was delighted to find that the falsity of the official version is common knowledge among a small group of scholars. All the more puzzling, then, that the standard, heroic account continues to hold sway.

What is so wrong with the official tale, as epitomized in my eight points above? We should begin by analyzing the very few eyewitness accounts recorded right after the event itself.

Turning to reports by journalists, we must first mark the outstanding negative evidence. In a nation with a lively press, and with traditions for full and detailed reporting (so hard to fathom from our age of television and breathless paragraphs for the least common denominator), the great debate stands out for its nonattention. *Punch,* Wilberforce's frequent and trenchant critic, ignored the exchange but wrote poem and parody aplenty on another famous repartee about evolution from the same meeting—Huxley versus Owen on the brains of humans and gorillas. The *Athenaeum,* in one of but two accounts (the other from *Jackson's Oxford Journal*), presents a straightforward

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report that, in its barest outline, already belies the standard version in two or three crucial respects. On July 7, the reporter notes Oxford's bucolic charms: "Since Friday, the air has been soft, the sky sunny. A sense of sudden summer has been felt in the meadows of Christ Church and in the gardens of St. John's; many a dreamer of dreams, tempted by the summer warmth . . . and stealing from section A or B [of the meeting] has consulted his ease and taken a boat." But we then learn of a contrast between fireworks inside and punting lazily downstream while taking one's *dolce far niente.*

The Bishop of Oxford came out strongly against a theory which holds it possible that man may be descended from an ape . . . . But others—conspicuous among these, Prof. Huxley—have expressed their willingness to accept, for themselves, as well as for their friends and enemies, all actual truths, even the last humiliating truth of a pedigree not registered in the Herald's College. The dispute has at least made Oxford uncommonly lively during the week.

The next issue, July 14, devotes a full page of tiny type to Dr. Draper and his aftermath—the longest eyewitness account ever penned. The summary of Wilberforce's remarks indicates that his half-hour oration was not confined to gibe and rhetoric, but primarily presented a synopsis of the competent (if unoriginal) critique of the *Origin* that he later published in the *Quarterly Review* (see last month's column for an analysis of Wilberforce's arguments). The short paragraph allotted to Huxley's reply does not mention the famous repartee—an omission of no great import in a press that, however detailed, could be opaquely discreet. But the account of Huxley's words affirms what all letter writers (see below) also noted—that Huxley spoke briefly and presented no detailed refutation of the bishop's arguments. Instead, he focused his remarks on the logic of Darwin's argument, asserting that evolution was no mere speculation, but a theory supported by copious evidence even if the process of transmutation could not be directly observed.

By the standard account, chaos should now break out, Fitzroy should jump up raving, and Henslow should gavel the meeting closed. No such thing; the meeting went on. Fitzroy took the podium in his turn. Two other speakers followed. And then, the true climax—not entirely omitted in Francis Darwin's "official" version so many years later, but so relegated to a few lines of afterthought that the incident simply dropped out of most later accounts—leading to the popular impression that Huxley's riposte had ended the meeting. Henslow turned to Joseph Hooker, the botanist of Darwin's inner circle, and asked him "to state his view of the botanical aspect of the question."

The *Athenaeum* gave Hooker's remarks four times the coverage awarded to Huxley. It was Hooker who presented a detailed refutation of Wilberforce's specific arguments. It was Hooker who charged directly that the bishop had distorted and misunderstood Darwin's theory. We get some flavor of Hooker's force and effectiveness from a section of the *Athenaeum's* report:

In the first place, his Lordship, in his eloquent address, had as it appeared to him [Hooker], completely misunderstood Mr. Darwin's hypothesis: his Lordship intimated that this maintained the doctrine of the transmutation of existing species one into another, and had confounded this with that of the successive development of species by variation and natural selection. The first of these doctrines was so wholly opposed to the facts, reasonings and results of Mr. Darwin's work, that he could not conceive how any one who had read it could make such a mistake—the whole book, indeed, being a protest against that doctrine.

Moreover, it was Hooker who presented the single most effective debating point against Wilberforce (according to several eyewitness accounts) by stating publicly that he had long opposed evolution but had been led to the probable truth of Darwin's claim by so many years of direct experience with the form and distribution of plants. The bishop did not respond, and Henslow closed the meeting after Hooker's successful speech.

When we turn to the few letters of eyewitnesses, we find the *Athenaeum* account affirmed, the official story further compromised, and some important information added—particularly on the exchange about apes and ancestors. We must note, first of all, that the three letters most commonly cited—those of Green, Fawcett, and Hooker himself—were all written by participants or strong partisans of Darwin's side. For example, future historian J.R. Green, source of the standard version for Huxley's actual words, began his account (to the geologist W. Boyd Dawkins) with a lovely Egyptian metaphor of fealty to Darwin:

On Saturday morning I met Jenkins going to the Museum. We joined company, and he proposed going to Section D, the Zoology, etc. "to hear the Bishop of Oxford smash Darwin." "Smash Darwin! Smash the Pyramids," said I in great wrath . . . .

(These one-sided sources make Balfour Stewart's neglected letter all the more important—for he was the only uncommit-

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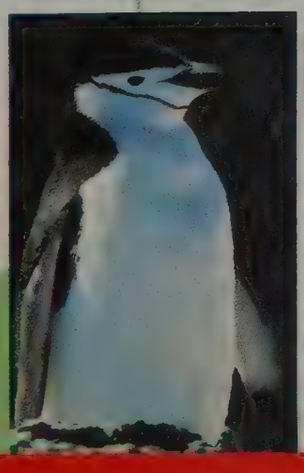

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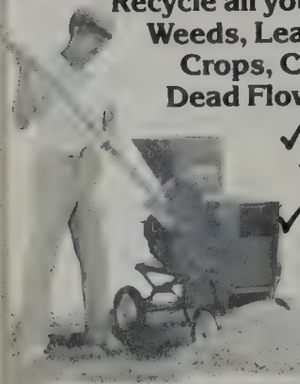

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ted scientist who reported his impressions right after the debate.)

We may draw from these letters, I believe, three conclusions that further refute the official version. First, Huxley's words may have rung true, but his oratory was faulty. He was ill at ease (his great career as a public speaker lay in the future). He did not project; many in the audience did not hear what he said. Hooker wrote to Darwin on July 2:

> Well, Sam Oxon [short for *Oxoniensis*, Latin for "of Oxford," Wilberforce's ecclesiastical title] got up and spouted for half an hour with inimitable spirit, ugliness and emptiness and unfairness . . . . Huxley answered admirably and turned the tables, but he could not throw his voice over so large an assembly, nor command the audience; and he did not allude to Sam's weak points nor put the matter in a form or way that carried the audience.

The chemist A. G. Vernon-Harcourt could not recall Huxley's famous words many years later because he had not heard them over the din. He wrote to Leonard Huxley: "As the point became clear, there was a great burst of applause, which mostly drowned the end of the sentence."

Second, for all the admitted success of Huxley's great moment, Hooker surely made the more effective rebuttal—and the meeting ended with his upbeat. I hesitate to take Hooker's own account at face value, but he was so scrupulously modest and self-effacing, and so willing to grant Huxley all the credit later on as the official version congealed, that I think we may titrate the adrenaline of his immediate joy with the modesty of his general bearing and regard his account to Darwin as pretty accurate:

> My blood boiled, I felt myself a dastard; now I saw my advantage; I swore to myself that I would smite that Amalekite, Sam, hip and thigh . . . .There and then I smashed him amid rounds of applause. I hit him in the wind and then proceeded to demonstrate in a few words: (1) that he could never have read your book, and (2) that he was absolutely ignorant of the rudiments of Bot [botanical] Science. I said a few more on the subject of my own experience and conversion, . . . Sam was shut up—had not one word to say in reply, and the meeting *was dissolved forthwith* [Hooker's italics].

Third, and most important, we do not really know what either man said in the famous exchange about apes and ancestors. Huxley's retort is not in dispute. The eyewitness versions differ substantially in wording, but all agree in content. We might as well cite Green's version, if only because it became canonical when Huxley himself "approved" it for Francis Darwin's biography of his father:

> I asserted, and I repeat—that a man has no reason to be ashamed of having an ape for his grandfather. If there were an ancestor whom I should feel shame in recalling, it would rather be a *man*, a man of restless and versatile intellect, who, not content with an equivocal success in his own sphere of activity, plunges into scientific questions with which he has no real acquaintance, only to obscure them by an aimless rhetoric, and distract the attention of his hearers from the real points at issue by eloquent digressions and skilled appeals to religious prejudice.

Huxley later demurred only about the word "equivocal," asserting that he would not have besmirched the bishop's competence in matters of religion.

Huxley's own, though lesser-known version (in a brief letter written to his friend Dyster on September 9, 1860) puts the issue more succinctly, but to the same effect:

> If then, said I, the question is put to me would I rather have a miserable ape for a grandfather or a man highly endowed by nature and possessed of great means of influence and yet who employs those faculties and that influence for the mere purpose of introducing ridicule into a grave scientific discussion—I unhesitatingly affirm my preference for the ape.

But what had Wilberforce said to incur Huxley's wrath? Quite astonishingly, on this pivotal point of the entire legend, we have nothing but a flurry of contradictory reports. No two accounts coincide. All mention apes and grandfathers, but beyond this anchor of agreement, we find almost every possible permutation of meaning.

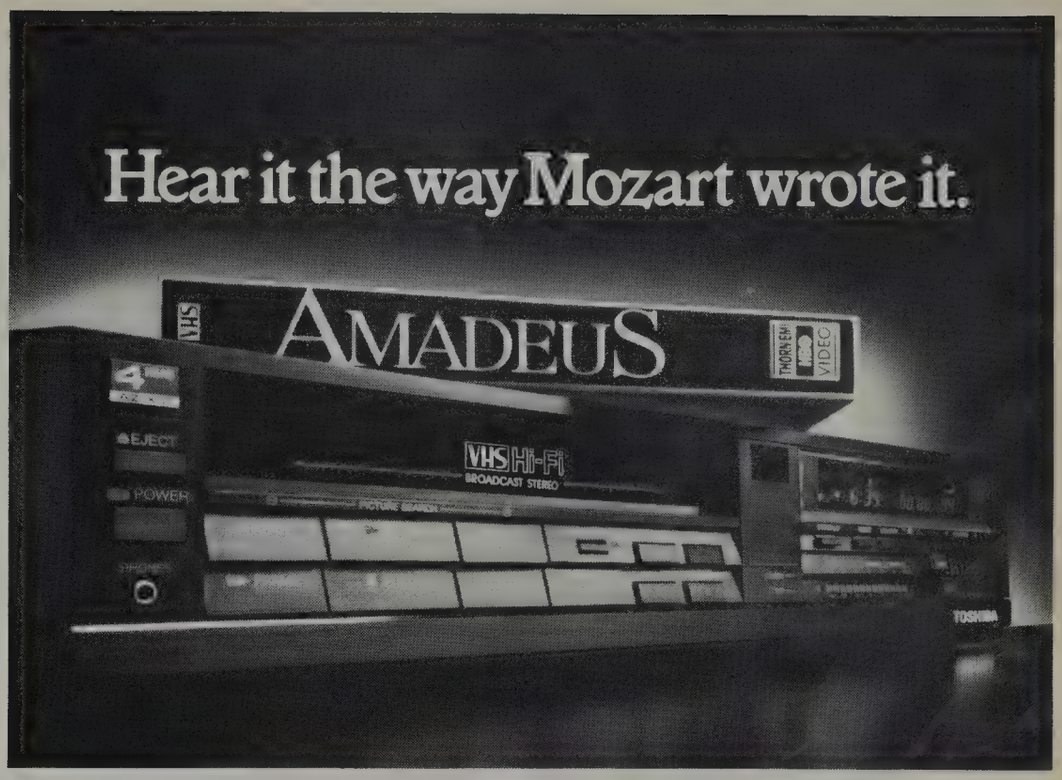
We don't know, first of all, whether or not Wilberforce committed that most dubious imposition upon Victorian sensibilities by daring to mention *female* ancestry from apes—that is, did he add grandmothers or speak only of grandfathers? Several versions cite only the male parent, as in Green's letter: "He [Wilberforce] had been told that Professor Huxley had said that he didn't see that it mattered much to a man whether his grandfather was an ape or not. Let the learned professor speak for himself." Yet, I am inclined to the conclusion that Wilberforce must have said something about grandmothers. The distaff side of descent occurs in several versions, Balfour Stewart's neglected letter in particular (see earlier citation), by disinterested observers or partisans of Wilberforce. I can understand why opponents might have delighted in such an addition ("merely corroborative detail, intended to give artistic verisimilitude to an otherwise bald and unconvincing narrative," as Pooh-Bah liked to say). But why

should sympathetic listeners remember such a detail if the bishop had not included it himself?

But, far more importantly, it seems most unlikely that the central claim of the official version can be true—namely, that Wilberforce taunted Huxley by asking him pointedly whether he could trace his personal ancestry from grandparents back to apes (made all the worse if the bishop really asked whether he could trace it on his mother's side). No contemporary account puts it quite so baldly. The official version cites a letter from Lyell (who was not there) since the anonymous eyewitness (more on him later) who supplied Francis Darwin's account could not remember the exact words. Lyell wrote: "The Bishop asked whether Huxley was related by his grandfather's or grandmother's side to an ape." The other common version of this taunt was remembered by Isabel Sidgwick in 1898: "Then, turning to his antagonist with a smiling insolence, he begged to know, was it through his grandfather or his grandmother that he claimed his descent from a monkey?"

We will never know for sure, but the memories of Canon Farrer seem so firm and detailed, and ring so true to me, that I shall place my money on his version. Farrar was a liberal clergyman who once organized a meeting for Huxley to explain Darwinism to fellow men of the cloth. His memories, written in 1899 to Leonard Huxley, are admittedly forty years old, but his version makes sense of many puzzles and should be weighted well on that account—especially since he regarded Huxley as the victor and did not write to reconstruct history in the bishop's cause. Farrar wrote, taking the official version of Wilberforce's taunt to task:

His words are quite misquoted by you (which your father refuted). They did not appear vulgar, nor insolent nor personal, but flippant. He had been talking of the perpetuity of species in birds [a correct memory since all agree that Wilberforce criticized Darwin on the breeds of pigeons in exactly this light]: and then denying *a fortiori* the derivation of the species Man from Ape, he rhetorically invoked the help of feeling: and said (I swear to the sense and form of the sentence, if not to the words) "If anyone were to be willing to trace his descent through an ape as his grandfather, would he be willing to trace his descent similarly on the side of his grandmother." It was (you see) the arousing of antipathy about degrading women to the Quadrumana [four-footed apes]. It was not to the point, but it was the purpose. It did not sound insolent, but unscientific and unworthy of the zoological argument which he had been sustaining. It was a bathos. Your father's reply . . . showed that there was a



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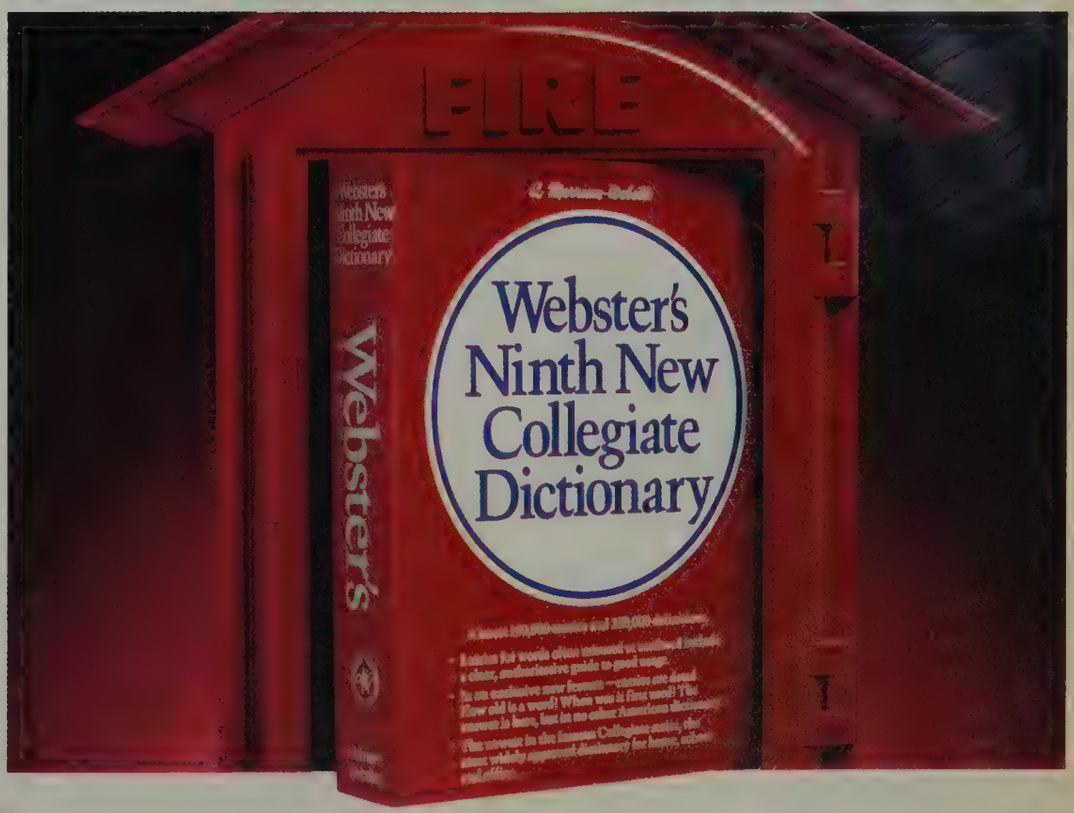

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vulgarity as well as a folly in the Bishop's words; and the impression distinctly was, that the Bishop's party as they left the room, felt abashed; and recognized that the Bishop had forgotten to behave like a gentleman.

Farrar's analysis of Huxley's victory includes an interesting comment on Victorian sensibilities:

The victory of your father, was not the ironical dexterity shown by him, but the fact that he had got a victory in respect of manners and good breeding. You must remember that the whole audience was made up of gentlefolk, who were not prepared to endorse anything vulgar.

Finally, Farrar affirms the other major falsity of the official version by acknowledging the superiority of Hooker's reply:

The speech which really left its mark scientifically on the meeting, was the short one of Hooker . . . . I should say that to fair minds, the intellectual impression left by the discussion was that the Bishop had stated some facts about the perpetuity of species, but that no one had really contributed any valuable point to the opposite side except Hooker . . . but that your father had scored a victory over Bishop Wilberforce in the question of good manners.

And so, in summary, we may conclude that the heroic legend of the official version fails badly in two crucial points—our ignorance of Wilberforce's actual words and the near certainty that the forgotten Hooker made a better argument than Huxley. What, then, can we conclude, based on such poor evidence, about such a key event in the hagiography of science? Huxley did not debate Wilberforce at Oxford in 1860; rather, they both spoke, one after the other, in a prolonged discussion of Draper's paper. They had one short and wonderful exchange of rhetorical barbs on a totally nonintellectual point prompted by a whimsical remark, perhaps even a taunt, that Wilberforce made about apes and ancestry, though no one remembered precisely what he said. Huxley made a sharp and effective retort. Everyone enjoyed it all immensely and recalled it in a variety of versions. Some thought Huxley had won the exchange; others credit Wilberforce. Huxley hardly dealt with Wilberforce's case against Darwin. Hooker, however, made an effective reply in Darwin's behalf, and the meeting ended.

All events before the codification of the official version support this ambiguous and unheroic account. In particular, Wilberforce seemed not a bit embarrassed by the incident. Disraeli spoke about it in his presence. Wilberforce reprinted his review of Darwin's *Origin,* the basis of his

remarks that fateful day, in an 1874 collection of his works. His son recounted the tale with credit in Wilberforce's biography. Moreover, Darwin and Wilberforce remained on good terms. The ever genial Darwin wrote to Asa Gray that he found Wilberforce's review "uncommonly clever, not worth anything scientifically, but quizzes me in splendid style. I chuckled with laughter at myself." Wilberforce, told by the Vicar of Downe about Darwin's reaction, said: "I am glad he takes it in this way. He is such a capital fellow."

Moreover, though I don't believe that self-justification provides much evidence for anything, we do have a short testimony from Wilberforce himself. He wrote to Sir Charles Anderson just three days after the event: "On Saturday Professor Henslow who presided over the Zoological Section called on me by name to address the Section on Darwin's Theory. So I could not escape and had quite a long fight with Huxley. I think I thoroughly beat him." This letter, now housed in the Bodleian Library of Oxford University, escaped all notice until 1978, when Josef L. Altholz cited it in the *Journal of the History of Medicine*. I would not exaggerate the importance of this document because it smacks of insincerity at least once—so why not in its last line as well? We know that 700 people crammed the museum's largest room to witness the proceedings. They didn't come to hear Dr. Draper on the intellectual development of Europe. Wilberforce was on the dais, and if he didn't know that he would speak, how come everyone else did?

Why then, and how, did the official version so color this event as a primal victory for evolution? The answer largely lies with Huxley himself, who successfully promoted, in retrospect, a version that suited his purposes (and had probably, by then, displaced the actual event in his memory). Huxley, though not anti-religious, was uncompromisingly and pugnaciously anticlerical. Moreover, he despised Wilberforce and his mellifluous sophistries. When Wilberforce died in 1873, from head injuries sustained in a fall from his horse, Huxley remarked (as the story goes): "For once, reality and his brains came into contact and the result was fatal."

Janet Browne has traced the construction of the official version in Francis Darwin's biography of his father. The story is told through an anonymous eyewitness, but Browne proves that Hooker himself wrote the account, volunteering for the task with direct purpose (writing to Francis): "Have you any account of the Oxford meeting? If not, I will, if you like, see what I can do towards vivifying it (and vivisecting the Bishop) for you." Hooker dredged his memory with pain and uncertainty. He had forgotten his letter to Darwin and admitted, "It is impossible to be sure of what one heard, or of impressions formed, after nearly thirty years of active life." And further, "I have been driven wild formulating it from memory." Huxley then vetted Hooker's account and the official story was set.

The tale was then twice embellished—first, in 1892, when Francis published a shorter biography of Charles Darwin, and Huxley contributed a letter, now remembering for the first time (more than thirty years later) his *sotto voce* crack, "the Lord hath delivered him into mine hands"; second, in 1900, when Leonard Huxley wrote the life of his father. Thus, dutiful sons presented the official version as constructed by a committee of two—the chief participants Huxley and Hooker—from memories colored by thirty years of battle. We can only agree with Sheridan Gilley who writes:

The standard account is a wholly one-sided effusion from the winning side, put together

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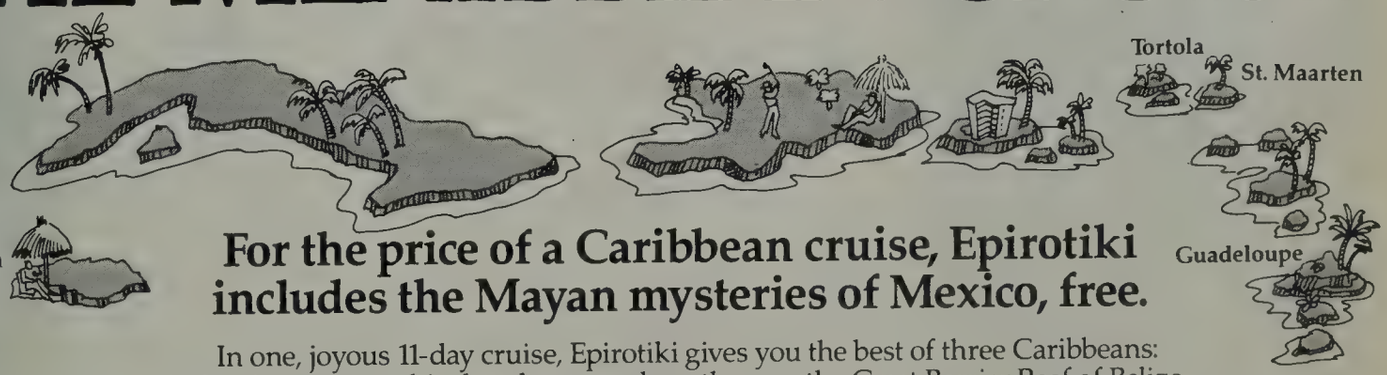

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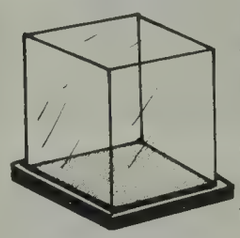

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long after the event, uncritically copied from book to book, and shaped by the hagiographic conventions of the Victorian life and letters.

So much for correcting a moment of history. But why should we care today? Does the heroic version do any harm? And does its rectification have any meaning beyond our general preference for accuracy? Stories do not become primary legends simply because they tell rip-roaring narratives; they must stand as exemplars, particular representations of something deeper and far more general. The official version of Huxley versus Wilberforce is an archetype for a common belief about the nature of science and its history. The fame and meaning of the official version lie in this wider context. But this common belief is not only wrong (or at least seriously oversimplified) but ultimately harmful to science. Thus, in debunking the official version of Huxley versus Wilberforce, we might make a helpful correction for science itself.

Ruth Moore captured the general theme in her version of the standard account: "From that hour on, the quarrel over the elemental issue that the world believed was involved, science versus religion, was to rage unabated." The story has archetypal power because Huxley and Wilberforce, in the official version, are not mere men but symbols, or synecdoches, for a primal struggle: religion versus science, reaction versus enlightenment, dogma versus truth, darkness versus light.

All men have blind spots, however broad their vision. Thomas Henry Huxley was the most eloquent spokesman that evolution has ever known. But his extreme anticlericalism led him to an uncompromising view of organized religion as the enemy of science. Huxley could envision no allies among the official clergy. Conservatives like Wilberforce were enemies pure and simple; liberals lacked the guts to renounce what fact and logic had falsified, as they struggled to marry the irreconcilable findings of science with their supernatural vision. He wrote in 1887 of those "whose business seems to be to mix the black of dogma and the white of science into the neutral tint of what they call liberal theology." Huxley did view his century as a battleground between science and organized religion—and he took great pride in the many notches on his own gun.

This cardboard dichotomy seems favorable for science at first (and superficial) glance. It enshrines science as something pure and apart from the little quirks and dogmas of daily life. It exalts science as a disembodied method for discovering truth

at all costs, while social institutions—religion in particular—hold fast to antiquated superstition. Comfort and social stability resist truth, and science must therefore fight a lonely battle for enlightenment. Its heroes, in bad times, are true martyrs—Bruno at the stake, Galileo before the Inquisition—or, in better times, merely irritated, as Huxley was, by ecclesiastical stupidity.

But no battle exists between science and religion—the two most separate spheres of human need. A titanic struggle occurs, always has, always will, between questioning and authority, free inquiry and frozen dogma—but the institutions representing these poles are not science and religion. These struggles occur *within* each field, not primarily across disciplines. The general ethic of science leads to greater openness, but we have our fossils, often in positions of great power. Organized religion, as an arm of state power so frequently in history, has tended to rigidity—but theologies have also spearheaded social revolution. Official religion has not opposed evolution as a monolith. Many prominent evolutionists have been devout, and many churchmen have placed evolution at the center of their personal theologies. Henry Ward Beecher, America's premier pulpiteer during Darwin's century, defended evolution as God's way in a striking commercial metaphor: "Design by wholesale is grander than design by retail"—better, that is, to ordain general laws of change than to make each species by separate fiat.

The struggle of free inquiry against authority is so central, so pervasive that we need all the help we can get from every side. Inquiring scientists must join hands with questioning theologians if we wish to preserve that most fragile of all reeds, liberty itself. If scientists lose their natural allies by casting entire institutions as enemies, and not seeking bonds with soul mates on other paths, then we only make a difficult struggle that much harder.

Huxley had not planned to enter that famous Oxford meeting. He was still inexperienced in public debate, not yet Darwin's bulldog. He wrote: "I did not mean to attend it—did not see the good of giving up peace and quietness to be episcopally pounded." But his friends prevailed upon him, and Huxley, savoring victory, left the meeting with pleasure and resolution:

> Hooker and I walked away from the meeting together, and I remember saying to him that this experience had changed my opinion as to the practical value of the art of public speaking, and that from that time forth I should carefully cultivate it, and try to leave off hating it.

So Huxley became the greatest public spokesman for science in his century—as a direct result of his famous encounter with Wilberforce. He waded into the public arena and struggled for three decades to breach the boundaries between science and the daily life of ordinary people. And yet, ironically, his Manichean view of science and religion—abetted so strongly by the official version, constructed in part by himself, of his debate with Wilberforce—harmed his greatest hope by establishing boundaries to exclude natural allies and, ultimately, by encircling science as something apart from other human passions. We may, perhaps, read one last document of the great Oxford debate in a larger metaphorical context as a plea, above all, for solidarity among people of like minds and institutions of like purposes. Darwin to Hooker upon receiving his account of the debate: "Talk of fame, honor, pleasure, wealth, all are dirt compared with affection."

Stephen Jay Gould teaches biology, geology, and the history of science at Harvard University.

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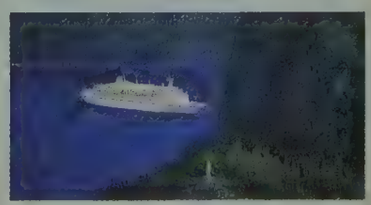

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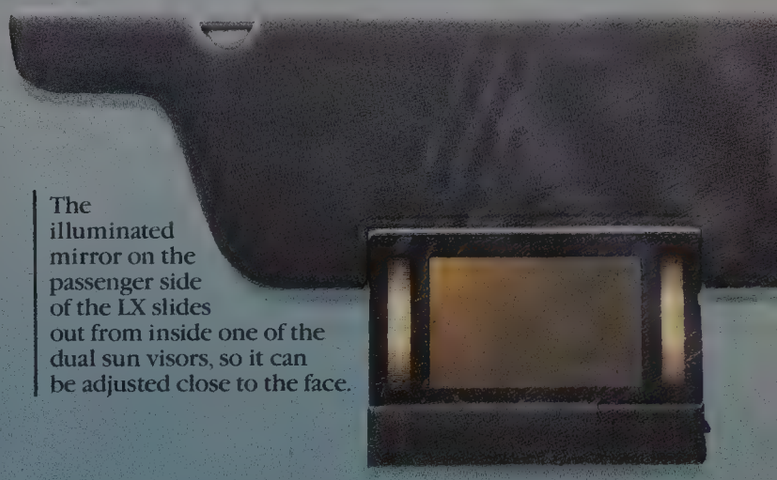

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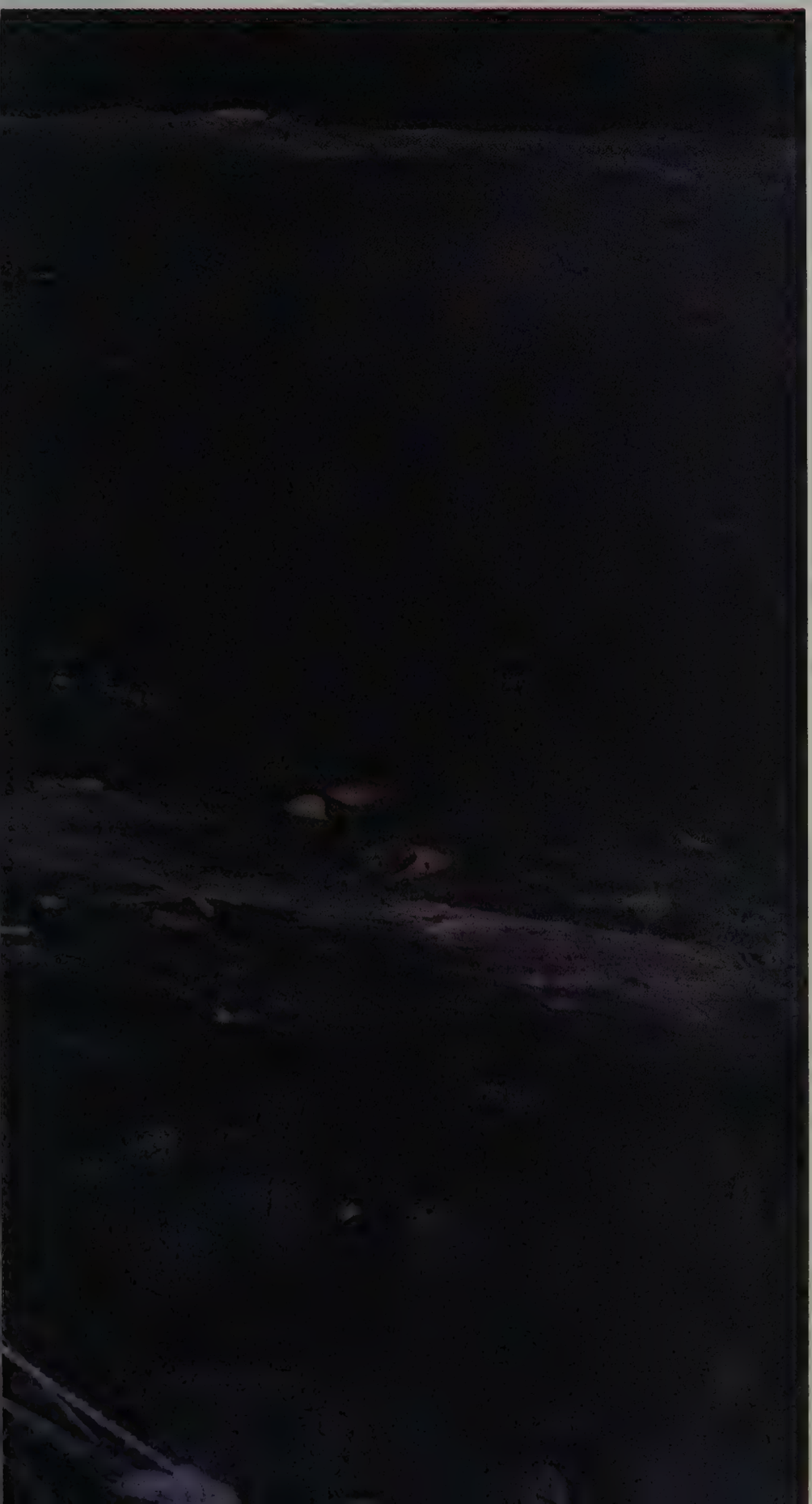
In the rain forest of northeastern Luzon, two young women crouch near a game trail, waiting for prey being driven toward them by another hunter and dogs. Bows and arrows are effective for bringing down wild pigs, deer, and other animals on the run.

All photographs by Agnes Estioko-Griffin and P. Bion Griffin

Daughters of the Forest

Agta women of the Philippines hunt large game animals and still raise their children

by Agnes Estioko-Griffin



In the textbook-case foraging society, hunting is a man's job. Anthropologists argue that a sexual division of labor makes sense. Women seem less suited physically for such strenuous activity, and in any case, hunting entails many risks that might endanger their children. The woman's role is to bear and raise babies, dig roots, pick berries, and maybe catch the occasional rabbit. Discussing "The Evolution of Hunting," Sherwood L. Washburn and C.S. Lancaster wrote that "when males hunt and females gather, the results are shared and given to the young, and the habitual sharing between a male, a female, and their offspring becomes the basis for the human family" (in *Man the Hunter,* edited by Richard B. Lee and Irven DeVore).

Taytayan Taginod and other Agta women in the Philippines have not heard this anthropological wisdom and would laugh if they did. Taytayan, now a young grandmother, has long hunted wild "bearded pigs," deer, monkeys, and a variety of smaller forest animals and has spearfished in dangerous rivers.

The Agta live in the Sierra Madre, a heavily forested mountain range that parallels the rugged Pacific coast of northeastern Luzon. The Agta do exploit some ocean resources, but it is the humid rain forest and its streams and rivers that dominate their lives. Traditionally, the forest provided not only food but also bark for clothing, palm fronds and saplings for houses, leaves for bedding, and wood for tools. Today, the Agta obtain metal tools, manufactured cloth, cooking pots, tobacco, and rice in trade for forest products—meat and fish, rattan, orchids, and Manila copal, a tree resin.

Extended family groups—clusters of two or three brothers and sisters, the old folks, and the children—are the living and working units of Agta society. All men hunt, except those living where the encroachment of agricultural groups has decimated the forest and game. Where only Agta live, game is plentiful. Wild pig and deer are abundant, although they fluctuate in numbers through various cycles. Plant foods are less readily available. Wild roots are scattered, difficult to dig,

and give low returns for the effort expended. Today, Agta dig wild roots only in times of real hardship or when they feel a desire for traditional foods. They grow upland (dry) rice, corn, cassava, and sweet potatoes, but the yield from these crops is low. Given this situation, the Agta say it makes sense for women to be hunters. Women vary in their patterns of living, but many hunt and nearly all join the men in driving game.

Agta women differ from men in hunting tactics. Men love to enter the forest alone, where they stalk with bow and arrow, wait in ambush for hours by fallen fruit, or spot game at night with flashlights tied to their heads. Women are team hunters. They work with other women or with their men. They almost always prefer to drive with dogs and favor killing with long knives instead of bows and arrows (arrows are apt to endanger the dogs). They are seldom the fanatics that men are, but for some women, love of the hunt dominates all their work.

Taytayan is one of the enthusiasts, as my husband, P. Bion Griffin, and I learned as anthropological guests of her family. Taytayan learned to hunt from her husband, Galpong, whose second wife she had become at age sixteen. Taytayan's older sister, Littawan, was Galpong's first wife. Littawan had been unable to conceive; rather than divorce her, Galpong had taken the younger sister as well. Taytayan soon loved hunting with Galpong or Littawan or both. By the time we became acquainted, all three were mature adults and very successful hunters. Taytayan hunts several times a week, choosing, as the more active women hunters often do, to carry the bow and arrow and to nurture a pack of hunting dogs.

I recall the time she ran a deer for two days, until its feet were raw and bloody and exhaustion had slowed it to the point it could be shot. She had given up the hunt the first day, but the next day, she took her dogs, found the deer, and chased it until it collapsed. Other times she and Littawan hunted, Taytayan leaping ahead to shoot and kill, then asking Littawan to carry the carcass home. The kill, she felt, was fun, but lugging a pig home was no joy at all.

Taytayan takes pleasure in the Agta pastime of telling the story of a hunt. The presence of a tape recorder spurs her and others on, and gives the anthropologists (who can seldom keep up during the actual chase) a better insight into the activity. While Taytayan readily tells the stories of both successful and unsuccessful hunts, the following excerpt reveals much of the character and action of a good hunt.

"Littawan and I took off and walked way upstream. . . . 'Say, here are some deer tracks,' I said. We went up the side of Tagemuyo Mountain. No tracks there. We walked up the stream bed and crossed. We saw more deer tracks. The dogs were all over the hillside. We kept on but saw nothing. We crossed the stream again and went farther upstream. Those deer were really hiding. 'Hala, ha, ha, ha,' a monkey cried. 'Huu, huu,' I called to the dogs. Upstream there were more tracks. We continued, and I said, 'There are to many tracks! Where are the dogs?' 'Aa aah,' I called to the dogs. I grouped th dogs together where the tracks were clu tered. The dogs wouldn't stay togethe and one, Tighe, was off on his own.

" 'Listen! That's a pig!' I said; 'Quic after it!' Littawan urged the dogs on b calling 'Arah, arah, arah, arah!' 'Hurry u to the next stream!' she yelled. I ra around a pile of fallen rocks and earth an into a swarm of bees. They started stin ing me all over my body. My hands b came swollen; I was so upset I almo threw away my bow. I ran through th bushes and saw the pig, a large boar. Th dogs, Littawan, and I ran after it dow stream. I nocked my arrow; Tighe real bit the pig, but it broke loose. I couldn shoot for fear of hitting the dogs. I final got an arrow into it but didn't kill it. I the stabbed it several times.

Taytayan draws an arrow with a barbed tip made from scrap steel. When the arrow penetrates the prey, the point and shaft separate, and the shaft, attached to the point by a line, drags behind and encumbers the prey. This type of arrow is well suited for making the first shot at large game animals.

"Littawan arrived and tied the pig for carrying. 'Are we going to butcher it here or carry it home?' she asked. 'Let's butcher it over there,' I said, 'or we'll starve to death.' We roasted the liver and some sweet potatoes I was carrying, and then I said, 'Let's go downriver and spearfish.' On the way, we gathered grass for broom making to sell to the lowlanders. I spearfished but only got three fish.

"When we got home, I hollered, 'Bion, come and take our picture, as we are carrying meat.' I was carrying the grass and my bow and arrows over my shoulder. That would make a good picture."

While Taytayan learned to hunt after she married, most girls learn before they reach puberty. Later they develop into hunters or give it up, as it suits them. In our camp, which contained twenty-five people, girls of age ten and up accompanied fathers, mothers, aunts, and grandmothers on hunts. The girls carried knives or no weapons at all, but ran as game was taken, helped hold and control the dogs, and aided in butchering and carrying home the kills. They learned to recognize the signs of game animals, the fruit and leaves they eat, and how they behave under different conditions. Abey, Taytayan's elderly sister-in-law, recalls learning to hunt as a prepubescent girl:

"My mother and I left for the forest. We took the hunting dogs along. We walked upriver. 'The dogs are chasing a young wild pig!' called Mother. 'Hurry up before they chew it up.' 'I can't walk because of the thorns,' I answered. My mother got angry. 'I am going to leave you behind,' she threatened. I started to cry; I didn't want to be left in the forest. My mother hit me on the head with a stick. She ran off through the undergrowth and I grudgingly followed.

"We reached the place where the dogs had cornered the wild pig. My mother stabbed it with a knife until it died. She also hit the dogs because they kept attempting to drag the pig away. Still angry at me, she told me to carry the pig on my back. I took it down to the river to soak. I wanted to head home since I was already hungry. My mother, however, called the dogs and we proceeded upriver.

"The dogs jumped a deer, chased it, and bit its legs. It got away and ran into the river. Mother ran to it, held one of its legs, and stabbed it. 'Oh!' she screamed, 'It will gore me!' 'Take it into the deeper water!' I called. She grabbed and held the deer's head. It finally collapsed. 'Drag it to where the pig is,' she said. She butchered the deer. I gathered firewood, built a fire, and burned the hair off the pig. After Mother finished the deer, she butchered the pig. I roasted the liver and we both ate.

"Mother sent me to cut vines for making a pack to carry the meat. She gave me three legs to carry and we proceeded downriver. My pack was so heavy I was really staggering."

Now a grandmother, Abey is again the weak one, as she hunts with her older daughter, Iring. On one trip, she and Iring killed a pig; Iring carried her one-year-old son on her back. We photographed the dead pig and recorded Iring's tale:

" 'Let's keep on walking, Mother,' I said. She answered, 'Wait there for me, because my thighs hurt from climbing up the mountainside.' I walked along with my baby on my back. I was annoyed at Talengteng [the baby] because he was noisy while I was running. We climbed up the steep trail, I on my hands and knees . . . .

"Mother asked, 'What is that howling?' 'Ho, ho, ho,' howled [the dog] Baklayan. I thought, this old woman has weak hearing. That's just a young pig, judging from the pitch of the howling. I had to go faster because my mother couldn't run fast enough. As soon as the old woman arrived, she clubbed the pig on the head, but it wouldn't die. She clubbed it again, but it still would not die. I cut vines for tying the pig. She finished tying it, and I took the bow and arrows. The pig was still breathing hard tied to Mother's back. We walked and walked, rested, and chewed betel. While we descended the hill, Mother complained, 'That old dog is useless. It would have been better if I had reached the pig and stabbed it.' "

Just how effective are women hunters? My husband and I collected quantitative data and kept daily logs of activities. Of the 296 hunting trips we logged, men made 180, either singly or in groups that included no women. Another 61 trips were male–female team efforts. Trips involving only women numbered 55. Men, then, are more frequent hunters, but women also participate actively.

The greater frequency of hunting by men is reflected in the percentage of carcass weight they bring home. In our sample, men provided 43 percent of the animals by body weight. Hunting by women

accounted for 22 percent, while mixed teams got 35 percent. These figures are also the outcome of differences in hunting techniques.

Men use various tactics and often hunt alone. They lie in wait by fallen fruit to ambush the pigs and deer drawn to feed, or they stalk their prey under cover of jungle thickets. The average pig or deer killed by men using these tactics is larger than that brought down by women, although the better women hunters do kill large, adult game. The power of arrows shot from bows with sixty-pound pull also contributes to men's success in killing large animals. Women's bows seldom pull more than forty-five pounds. Of course, only the best hunters, male and female, regularly get the heaviest game.

While women's contribution by carcass weight is smaller, their hunting success rate is high. In the course of the 296 hunts we tabulated, 73 kills were made. The 180 "men only" trips brought in 31 kills, achieving a 17 percent rate of return. In comparison, women totaled 31 percent, and mixed teams of both men and women totaled 41 percent. These figures show that the use of teamwork and dogs yields the highest kill ratios.

Most of the trips by women involved dogs. Dog teams are expensive to maintain, perform poorly in rainy weather, and frequently die from game attacks, illness, or malnutrition. Well-trained, mature, healthy dogs, however, can be of critical importance to the hunt. Two different tactics may be used. In the first, hunters proceed into the forest and station themselves at ambush points where game is likely to pass. Then, one or more hunters with dogs enter the forest, hoping to surprise game and drive it to the ambushers. The second tactic is for a small team, say a husband and wife or two women, to travel with their dogs until an animal is located. Then, as Taytayan recounted, the chase is on, and the hunters expend huge amounts of energy covering rugged terrain. Very often the animal escapes, but good dogs help insure success.

Just as there is overlap, as well as a difference, in how men and women hunt in Agta society, so too the division of labor in other areas is a matter of emphasis. Everybody spearfishes, for example. Although women in foraging societies worldwide have usually been excluded from hunting, they have often been fishers in coastal and riverine environments.

Among the Agta, spearfishing is done under water, by swimmers wearing primitive goggles and using a large rubber band

Taytayan's elder daughter, Paola (left), spearfishes in a cold mountain river. The Agta use a large rubber band to propel a wire projectile. Agta females of all ages are skilled in this pursuit. Boys and girls, below, play a bow-and-arrow hunting game at the seashore.

) propel a wire projectile. Some fishing is
ı deep, fast, cold rivers; some in slow and
hallow streams. Children start learning to
sh when little more than toddlers, even-
ually turning play into a skill. Boys and
irls make forays to streams for safe, shal-
ow-water fishing, their catches becoming
icnic snacks. Teen-agers join adults in
shing the larger rivers where large fish
bound. Women truly excel in this often
aily activity. Nearly all females, from
welve years old to the very old, spearfish.

One of the most important of the Agta's
ood-getting pursuits, fishing may, in the
ry season, provide nearly all their animal
rotein for days at a time. Even people
/ho are not strong enough for the most
igorous fishing occasionally participate
ı the special fish drives. Women in ad-
anced pregnancy, the elderly, and the
ame may drag the rattan lines, tied with fronds, that span the river and chase fish to the swimmers.

Another large part of women's work among the Agta consists of gathering plant foods, shellfish, honey, and the multitude of items needed for medicines and camp maintenance. Even here, however, men are hardly excluded. Everybody collects honey, with women ably climbing the trees to cut down combs, except when young men can be talked into the task. (Women do not like to climb if they are wearing skirts; modest jogging shorts are the favored attire for work in the forest.) Frequently, all the adults and children in a camp take off for an outing along the beaches of rock and coral, where mollusks and crustaceans are to be had. Men limit their beach activities to spear and line fishing, however.

Women and children are the primary gatherers of wild roots and other plant foods. Men seldom join the women in digging up roots, whether cultivated or wild, and although they work at clearing and planting the family's small plot of dry rice, they are less likely to help harvest the crop. Whole families may work together in cutting the caryota palm tree, extracting the starch-laden pith, and packing the food home. More often, however, parties of women and girls do this arduous work, with lots of joking and horseplay throughout the long day.

As we examine all the work done by women, hunting and its supposed limitations on child rearing come into better perspective. Taytayan and her family exemplify efforts to harmonize food getting and general work with the bearing and raising of children.

Taytayan bore four children, two girls and two boys: only the two daughters survived. In this experience she was typical. We found that one-third to one-half of Agta children die before puberty. Tom Headland, a missionary-anthropologist working many miles to our south, found that about half the children die. In his area, the Agta have been more exposed to the destructive effects of newcomers—disease, alcohol, and depletion of game.

Children are a part of nearly all Agta activities. While older children may be left with baby sitters, nursing infants are carried on their mothers' backs not only on occasional hunting trips but also on forest excursions to secure building materials and food. This day in, day out exposure, which sometimes subjects them to wet and cold conditions, certainly contributes to the illnesses that kill many. Mothers shelter their children from bad weather whenever possible, however, and avoid

At a rainy-season camp, Taytayan, below, sets off on a hunt with her dogs. The rainy season from October to February, when spearfishing in flooded rivers is difficult and game animals are fat, is a favored time for hunting. A young father, right, lifts his children on his back before setting off on a foraging trip away from camp. Although women do the major share of child care, Agta men also help.

hunting under such conditions. So although hunting is rigorous, it does not pose any special danger to infants.

Taytayan's two daughters are now rearing families. The elder has four surviving children, while the younger, married only in 1978, has two. Both women learned to hunt with their mother, but now hunt primarily with their husbands. They neglect bows and arrows, preferring to carry only knives. During pregnancy they hunted less, and not until the babies were about six months old did they begin to carry them on short hunts.

Taytayan continues to go after wild pigs, deer, and monkeys, while also tending her grandchildren, even adopting the eldest. Now her companions include nieces, nephews, and, of course, Littawan. Her daughters find her difficult to keep up with because of her vigor and enthusiasm. Taytayan once expressed her interest in rumored "fertility drugs" to me. I asked how in the world she would hunt if she had another baby. "No problem," she said, "Littawan can carry it while we hunt."

Mothers and females in general are most decidedly the major child tenders in Agta society. Mothers do the greatest share, followed by elder sisters and grandmothers. Fathers are fourth, but still spend a significant amount of time caring for their children. Young fathers of two or three children assist their wives in child care every day. These fathers often carry older children, aged about three to eight, on foraging trips outside of camp, tending the children while mothers spearfish or gather. My husband and I have often joined these family expeditions. One of my husband's favorite activities was to accompany a father or grandfather and children on some forest task; the anthropologist had no trouble keeping up with the smaller children!

We even know one little girl of about seven, an only child, who was taken by her devoted father on short hunts. Of course, she did not hunt, and she had to be carried for part of the trip. She did, however, begin to take in the whole world of hunting—the sights, sounds, feelings, and spirit of moving through the jungle in hopes of killing prey. As she grows older, she will learn that women and men are not identical in hunting or in any other aspect of their lives. A division of labor by sex does exist in Agta society. But it is flexible, subject to individual needs and preferences. Women adjust hunting and child rearing to each other and to their other subsistence efforts. If they choose, they too can "bring home the bacon." □

Slipper snails attached to a turban snail

Riders in the Sea

Riding piggyback through the kelp beds, the hooked slipper snail finds life in the slow lane to its liking

From tide pool to deep rocky reef, through the vast kelp beds of the Monterey Peninsula, the hooked slipper snail, *Crepidula adunca,* rides its range on the backs of turban snails, top snails, miter snails, whelk, and even tiny carinated dove snails. Members of the genus are found throughout the tropical and temperate zones, and when not attached immobile to the rocky substrate, they will even take to the backs of horseshoe crabs.

In the nutrient-rich waters of Monterey Bay, amidst blooms of plankton and beds of large yellow-brown algae, we've seen how the hooked slipper snail has adapted its feeding and even its mating habits to preserve its sedentary ways. Instead of cruising the bay bottom in search of food, the snail feeds as it rides, filtering floating plankton and the detritus of decomposing kelp through long gill filaments adapted for feeding as well as respiration. The snails meet and mate on the backs of their hosts, and since juvenile males mature into females, even chance meetings of males may produce offspring. Two small males are often found attached to a larger female, all riding on the back of a host snail.

Fertilization is internal; males impregnate the underlying female and about 200 large yolky eggs are brooded in capsules beneath her foot. And while the floating eggs of their hosts develop into vulnerable planktonic larvae, hooked slipper snail offspring hatch into tiny fully formed snails, which avoid becoming drifting food by feeding on stored yolk beneath their mother's foot.

At one to two millimeters, the young launch out on their own but soon attach themselves to the shell of another snail, beginning their sessile life style. When tiny hooked slipper snails were put in an aquarium with various turban snails, within thirty minutes almost every juvenile had attached itself to a host. We

Photographs and text
by Lovell and Libby Langstroth

Overleaf: *Juvenile top snail hosts a tiny slipper snail*

Algae-encrusted slipper snails on red top snail

Turban snail bears slipper snails and barnacles

have even seen them attach themselves to marbles. Shell curvature, rather than shell inhabitant, appears to be the criterion for attachment, and the hooked slipper snail's own shell will grow to conform to the host's shell beneath. One turban snail in a tidal pool had as many as eight riders attached.

In the canopy of kelp sixty feet above the bottom of Monterey Bay, we have seen hundreds of turban and top snails, many with these slipper snails attached. There, by no doing of their own, the slipper snails stay under cover, protected from attacks by snail-hungry sea stars. The species is dispersed throughout its range by riding its roving hosts. In the kelp beds, breaking waves knock some snails and riders loose; others may drift long distances attached to plants torn free.

There is no evidence that the hooked slipper snail does any harm to its host, and it appears content to enjoy the fruits of passivity to the fullest. While it may trade up to a larger host, the snail eventually loses its own mobility, apparently none the worse for taking advantage of a free ride through life. □

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6.

CORPORATE AMERICA

BUSINESS SUPPORT OF CULTURAL INSTITUTIONS

By most measures, New York's Wooster Group is a success, with a lot of help from its friends. Increasingly, as must many other cultural organizations, the experimental theater group has to rely on its private, corporate friends for continuing success.

"Keeping the Group on salary is something we've never been able to do before," says general manager Linda Chapman. "There have been some difficult moments."

Ticket sales never would cover the Wooster Group's costs. Early government grants helped. Then the Group attracted modest but important contributions from some local corporations and foundations.

Public-Private Partnership

Such moments have been common in cultural pursuits since economic surplus first left room for culture. Whether it be the Metropolitan Opera or the Dance Theatre of Harlem, the American Museum of Natural History, the Cold Spring Harbor Whaling Museum, the Vienna State Opera or the Sistine Chapel ceiling, the natural sciences and fine arts have seldom been self-supporting.

Many cultural institutions and programs receive substantial support from public sources, but private funding is essential to meet the total need. Private funding includes individual contributions, large and small, foundations and corporate support. For all cultural organizations, private sources have become increasingly vital since public funding may be curtailed.

How the Private Sector Helps

Institutions large and small share the quest for corporate and other private support, for many of the same reasons.

Corporate and individual contributions, for example, accounted for 5% of the American Museum of Natural History's total revenues of $35.6 million in its 1984-1985 fiscal year. Grants and other restricted funds made up another 7%. This year the American Museum received more than a million dollars in unrestricted corporate contributions for the first time. "Our general

corporate campaign did well," says Robert G. Goelet, the museum's president.

Because of the scope of its scientific programs, the museum's constituency is virtually worldwide. Many of its relationships with such supporters as Mobil Corporation, Exxon, Philip Morris Inc., Chemical Bank and Bristol Myers have grown over decades. The Museum has been a New York City presence for 116 years, a resource both private and public sectors recognize for its role in the metropolitan area's cultural fabric.

"Museums such as ours," says Mr. Goelet, "are very important to the community culturally and economically. That's why New York City and New York State provide funds. Many corporation executives see the importance of supporting the big cultural institutions as they enhance the quality of life. They see that these organizations serve the interests of their employees, shareholders, and customers."

Companies today do seem to be increasing their support of cultural institutions. "Corporations are making their employees more aware of their matching gift programs and encouraging them to participate," Mr. Goelet says. "We're also seeing an increase in participation in corporate admissions programs. A corporation makes a contribution—in our case it's $10,000—and the museum then admits the firm's employees free of charge. Seventy companies now participate in our admissions program."

The steady, ongoing contributions from corporations with strong budgets for unrestricted annual support are perhaps the most valuable of all to an established cultural institution. American Express, Bankers Trust, Bristol Myers, CBS Inc., Chemical Bank, Citicorp/Citibank, Consolidated Edison, Exxon, General Foods, Johnson and Higgins, IBM, McGraw Hill Inc., Metropolitan Life, Morgan Guaranty Trust Co., Mobil, New York Telephone, the New York Times, Philip Morris Inc., Time Inc. and United States Steel are among such stalwarts.

Another cultural resource with wide natural-science interests and support needs is the New York Zoological Society. The Society's best known operation is the world-renowned Bronx Zoo. Others include the New York Aquarium, the Osborn Marine Laboratory, and Wildlife Conservation International, the oldest American international conservation program.

To support these many ventures takes money. The Society's fiscal 1985 revenues were $31.7 million. These funds came from a combination of earned income, state and municipal sources, and gifts and contributions—the latter roughly equating to private-sector funding.

That mix, says director of public affairs James W. Meeuwsen, has changed greatly over time. Meeuwsen says, "our activities now place a greater demand on our income from private sources."

The New York Botanical Garden, whose revenue totalled $7.8 million, receives a significant portion of its funds from corporate and other private sources. "These funds support three areas: horticulture, science, and education," says Robert Wilkins, vice president for development and public relations. "We get support from New York companies and many national ones too."

Cultural funding may also be on a smaller scale and local. One elated organization this year is the East Hampton Historical Society, which qualified in December for a $200,000 three-for-one matching grant from the National Endowment for the Humanities (NEH). The eastern Long Island society oversees six museums.

With an annual operating budget that increased from $70,000 five years ago to $240,000 today, East Hampton's historians now have an opportunity to match the new funds. It hopes to increase its traditional support from private foundations and individuals who have ties to the region, and from corporations.

The Patronage Tradition

From antiquity, political and financial nobility has patronized the arts and sciences. Historically, the tradition of public support has been stronger outside the United States. In a 1985 study, J. Mark Davidson Shuster of the Massachusetts Institute of Technology noted that France, Sweden, West Germany, the Netherlands, and Canada all provided about $30 per capita in public expenditures on the arts, while Great Britain, Italy, and the U.S. provided only $10 to $13 per capita. The higher level of private donations in the U.S., though, allows support here to be restated as a total of $23 per capita.

The tradition of private cultural patronage began in America with the builders of the great 19th-century commercial and industrial fortunes. In time, most of these wealthy domains transmuted into corporations, owned by shareholders rather than families. The question then became: Should corporate America now assume the role of cultural support?

The answer was not a clear "yes." As recently as the 1960s, many doubted that stockholders would tolerate "their" companies using "their" money to support culture.

Sybil C. Simon, founder and executive director of the Arts & Business Council, says that a landmark study on business and culture carried out 20 years ago by the Rockefeller Brothers Fund focused the issue. Even with projected government support, the report concluded that the private sector should also do its part. A 1966 conference, says Ms. Simon, "exploded the theory that stockholders would object."

Growth In Corporate Support

Since then, corporate America has heeded that call. The Business Committee for the Arts, Inc., (BCA) founded in 1967 and with a membership today of more than 160 senior corporate executives, estimates that, in 1969, business support stood at $22 million from a few dozen enterprises. By 1982, cultural support had exceeded $500 million annually from many more corporations. Next year, BCA hopes its 20th anniversary will show corporate support for cultural events and institutions to have topped a billion dollars.

Broader studies say that it already has. A survey by Chemical Bank shows that just since 1979, "private giving grew from $2.7 billion to $5.4 billion."

Some corporations in recent years have almost alone equaled the total level of corporate cultural support in the late 1960s.

The Coca-Cola Foundation, established only in 1984,

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gave $5.2 million that year, 25% of it to cultural organizations and events. Citicorp USA's total contributions reached $8.5 million in 1984 and $8.9 million in 1985, with slightly more than a fourth allocated to cultural activities. The Ford Motor Company Fund gave $10 million in 1985, including $750,000 to culture. American Express in 1985 gave $11 million, a quarter going to culture. Atlantic Richfield Foundation contributed $35.8 million in 1984, of which $6.1 million supported the arts.

These funds go to many diverse beneficiaries. Pfizer, Inc., the New York based pharmaceutical company, is only one example of that diversity. The company and the Pfizer Foundation together made contributions totalling $5.5 million in 1984. "The company's contributions are very diverse," says spokesman John Sing. "The largest category is education at 31.7%. Next, as one might expect, is health care at 27.6%. Civic contributions total 23.3% and cultural 13.3%. Direct contributions to cultural organizations and events in 1984 (1985 figures aren't in yet) totalled $522,000 of which more than $400,000 came from the Foundation."

That half million covers a wide spectrum. The beneficiaries include the American Museum of Natural History, the Metropolitan Opera Association, the Museum of Modern Art, Carnegie Hall, the Lincoln Center for the Performing Arts, the National Trust for Historic Preservation, the New York City Opera, the Statue of Liberty/Ellis Island Foundation, the Old Globe Theater in Stratford, Connecticut, the Colonial Williamsburg Foundation, the Clearwater (Florida) Marine Science Center and the Boulder (Colorado) Philharmonic Orchestra. "There are at least fifty different organizations," says John Sing.

IBM spreads its largesse even wider. The company in 1985 gave $17 million to support cultural activities around the world.

Corporate cultural support goes beyond outright money gifts. Ten years ago, Sybil Simon's Arts & Business Council began a program to provide "in-kind" support. Business Volunteers for the Arts (BVA) has as its goal "to recruit, train and place corporate executives as *pro bono* consultants to cultural organizations in order to upgrade their management techniques." Already, Ms. Simon estimates, BVA has provided more than $11 million in volunteer time and other in-kind help.

"In-kind" covers a wide area. Johnson Wax donates its fine film "Living Planet" for use in the large screen theater of the American Museum of Natural History.

Business support of culture also appears in the contributions of dozens of American corporations to the nearly completed renovation of the Statue of Liberty. The public sector side of this support effort has been the U.S. Treasury Department's program to raise $50 million toward the restoration work through the marketing to the public, at no cost to taxpayers, of $5, $1, and 50-cent United States Liberty Coins.

Less well known is the help that corporations extend to individual artists and artisans. For example, Poets & Writers, Inc., an information exchange for poets and fiction writers founded in 1970 by Galen Williams, has nearly 100 company and foundation supporters. Similarly, the PEN American Center in New York has corporate funding for the PEN Syndicate Fiction project.

The Public Sector

In addition to aid from private sources, many cultural institutions receive substantial public support which added to private contributions help to make ends meet.

In the 1985 fiscal year, the National Endowment for the Humanities (NEH) had a budget of $139.8 million. The National Endowment for the Arts (NEA) had budget funding of $163.7 million in its 1985 fiscal year.

The federal budget appropriations for fiscal 1986 for NEA and NEH were $165.7 million and $138.6 million respectively. These appropriations, however, were reduced by the Gramm-Rudman balanced budget amendment. The proposed appropriations in the fiscal 1987 budget have been lowered still further to $158.5 million for NEA and $132.7 million for NEH. Not less than 20% of NEA's program funds must pass through to state and regional agencies and groups.

Similarly, New York State Council on the Arts makes grants in its own name and also works with New York's regional and local cultural bodies. In the 1985 budget year, New York State increased its direct funding for cultural activities from $35.3 million to $40.3 million. And through direct and pass-through funding, New York City raised its Cultural Affairs Department's budget to a record $129.7 million.

The Challenge

The array of private and public dollar support seems substantial today and apt to be more so tomorrow. But the future presents a challenge.

One element is the volatility of corporate earnings. As economic cycles occur, some businesses are able to give more or less at different times. Some other corporations are able to maintain a steady program of cultural support during these periodic ups and downs. An experienced fund-raiser observes that "it all balances out." In other words, corporations that are having hard times increase their contributions later when business improves.

Although petroleum industry earnings fluctuate, this industry has remained a steadfast supporter of cultural institutions. Oil companies are some of the largest enterprises and among the most giving cultural benefactors. The industry is perhaps most visible to the public through its support of public broadcasting. Exxon Corporation's Great Performances series, Mobil Corporation's Masterpiece Theater, and many nature series are underwritten in whole or part. Texaco boasts the longest continuous sponsorship of any program—the Saturday afternoon Metropolitan Opera On The Air, since 1940.

Aid is also given in less visible but no less appreciated ways. Special support from Mobil Corporation allows the American Museum of Natural History to remain open in the evenings.

The Museum has received other recent gifts for special purposes from Amerada Hess, the Starr Foundation, Newmont Mining, Engelhard Hanovia, Conoco Inc., the Anschutz Foundation, Exxon, IBM, the William Randolph Hearst Foundation, the Samuel and May Rudin Foundation and the Reader's Digest.

The challenge for not-for-profit organizations is to identify new business segments without a strong con-

Medical Research—building a healthier future

If you've ever been treated for high blood pressure... heart disease...diabetes...or almost any health problem, medical progress based on research has already touched your life.

Because of medical research, polio no longer strikes in epidemic proportions every summer. Today about three-quarters of patients diagnosed as having Hodgkin's disease will survive five years or longer—as opposed to less than half twenty years ago. Current treatment options for people with heart disease and high blood pressure include medication that helps the body's natural regulators to control blood pressure and volume, enabling the heart to function with less strain.

Scientists are now working on new ways of treating such devastating afflictions as heart disease, cancer and Alzheimer's disease. They are testing new enzyme inhibitors that may control or reverse the late complications of diabetes. Forthcoming breakthroughs in understanding biological processes and treating disease may change the quality and perhaps the length of your life.

Medical research leading to such results takes years of patient, often frustrating experimentation by many different teams throughout the public and private sectors of our scientific community. The tasks involved are not simple.

Advances in research stem from a partnership that includes federal agencies such as the National Institutes of Health (NIH), universities and teaching hospitals across America, and private industry laboratories. Each partner often works independently to acquire knowledge and test new concepts. They must build on the knowledge developed in all laboratories, and they often coordinate efforts in their search for answers.

Whether an idea originates in a university laboratory or starts with basic product research carried on in the private sector, important findings percolate through the entire scientific community, where each new finding serves as a building block to establish a deeper understanding of what we are and how we function.

Medical research is an expensive process. It needs steady funding for equipment and personnel—even when progress is slow. Government and industry often work with university-based scientists and the medical profession not only in the acquisition of new knowledge and the development of new treatments, but also in funding these advances.

Now more than ever, we all must do our part to help keep the flow of discoveries active and ongoing. If funding for medical research is reduced, major advances in knowledge about some of the most dreaded diseases facing us today could be delayed for years to come.

What can you do?

- *Speak up.* Let your legislators know that you want funding of biomedical research by NIH and other government agencies to be kept at the highest possible levels.
- *Contribute* to voluntary health organizations supporting disease research.

Research-based pharmaceutical companies such as Pfizer are also increasing their financial investment in research. For instance, in 1984 alone, pharmaceutical companies in the United States spent over 4 *billion* dollars on research and product development.

At the same time, we at Pfizer realize the importance of committing more than money to research. As a partner in healthcare, we are continually working to discover new ideas, test new concepts, and turn new understanding to practical and beneficial uses. Now we are working harder than ever to make sure that this nation's medical research effort receives the attention—and funding—it deserves.

For more information on the future of medical research in America, write to Health Research U.S.A., P.O. Box 3852 FR, Grand Central Station, New York, NY 10163.

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tributions history (technology, health and recreation industries) and discuss contributions with them.

Focus On Marketing Impact

Corporate restructuring is changing patterns of cultural support. The Bell System divestiture is one example. Prior to 1984, AT&T and its regional Bell units support of the arts was large-scale. The program dated to the "Bell Telephone Hour" broadcasts begun in 1940. AT&T's arts support is still large, and takes two distinct directions—one as corporate advertising, the other through the AT&T Foundation's programs.

The AT&T Foundation in 1985 made grants to the arts of $2.8 million, or 12% of its budget. This will increase by about 1% in 1986. "The Foundation carries on an AT&T tradition that emphasizes the performing arts and fosters new works," says Esther Novak, vice president for cultural programs.

Since divestiture, however, the Foundation is redirecting its funding. "We've shifted from relatively modest, unrestricted grants to more targeted project grants," Ms. Novak says. "That's largely because we're a smaller company, so we've got to focus our funds. We make fewer but larger grants."

Thus, where the AT&T Foundation would previously give to an orchestra's operating budget, it now will underwrite a specific series of concerts.

In its corporate advertising, AT&T today wants to project itself through cultural sponsorship as a national company with a presence everywhere in the U.S. "For five years," says Jackie Byrne, district manager for arts advertising, "we sponsored the tours of the 30 major American symphony orchestras. That was the beginning of our using cultural events for marketing purposes. Now, with divestiture, we are focusing on very special events and looking more closely at local markets."

In New York, that has meant supporting the Great Performers Series in Lincoln Center, and an international exhibition of painting and sculpture at the reopening of the Museum of Modern Art. AT&T also is the sole corporate underwriter of public television's MacNeil-Lehrer News Hour.

Merrill Lynch & Company Inc. also treats its cultural programs as a marketing arm. "We're a major international company," says corporate staff vice president Michael A. Wall, "but we're also a group of small offices around the world and especially across the U.S. So, when we work with cultural organizations in a market, we try to develop something new and different—and we also try to make sure people know we're doing this."

Through its special events program, budgeted annually at more than $2 million, Merrill has developed its Great Performers Series with 25 symphony orchestras and has been the sole corporate sponsor of the Metropolitan Opera's spring tour. It has worked with the New York City Ballet, the Boston Ballet, and the Goodman Theater in Chicago, and annually underwrites the Kennedy Center Honors Gala.

IBM's cultural support is broad-based, ranging from two-for-one backing of employee contributions to underwriting major programs around the world. These include a Renoir exhibition in Paris, London and Boston, and a Winslow Homer exhibit in Washington, D.C. Among performing arts support is an annual telecast of the American Ballet Theater's "Nutcracker." In 1983, the IBM Gallery of Science and Art opened at the firm's New York City midtown office building.

IBM in the 1930s also set a precedent by establishing one of the first corporate art collections. Its example has since been taken by such diverse firms as American Can Company, Chase Manhattan, Atlantic Richfield, NHG/Internorth in Omaha, and Ciba-Geigy Corporation in Ardsley, New York. Ciba also uses art to honor Blacks in the sciences, commissioning the artist Ernest Crichlow to do portraits of three noted Black scientists each year and using these as a basis for contributions to each scientist's university.

In a similar vein, many companies are donating valuable ground-floor space in their headquarters buildings to museums and exhibitions. The Philip Morris building in New York is a highly visible example. This corner of 42nd Street and Park Avenue is now an outpost of the Whitney Museum of American Art.

Delegating The Contributions Process

One trend in corporate support for cultural events and institutions may set a pattern for the future. Companies now delegate management of contributions programs to area managers. This approach not only mines all parts of the country for worthy projects, but fosters new types of grants.

Manufacturers Hanover Trust Company (MHT) focuses some of its effort on sports. Its special events unit sponsors the annual Westchester Golf Classic, the New York City Marathon, and the Corporate Challenge Series, a program of 3.5-mile road races for runners from other corporations. Says Barbara Paddock, the program's administrator, "MHT stages the events in a total of 13 cities where the company does business including London, England, and Dublin, Ireland."

Citicorp/Citibank's area managers use their authority over cultural gifts in socially meaningful as well as creative ways. Clarke Coggeshall, a vice president and area manager in Boston, has used his theater interests to gain two Citicorp "impact" grants of $25,000 for Boston's American Repertory Theatre.

Coggeshall also arranged an impact grant on quite another front: to support the FCD (Freedom from Chemical Dependency) Foundation's efforts to educate schoolchildren on drug and alcohol abuse. FCD's program is already used in many of New England's private schools, and now, backed by two $25,000 Citicorp matching grants, it is being introduced into 16 Boston public schools.

In the relationship between business and culture benefactor and beneficiary gain alike. "One of the distinguishing features of our program," says Elizabeth Howland, the Citicorp vice president in Chicago who administers contributions, "is that we've got fascinating people in the corporation whose enthusiasm and expertise will make us part of a community—a good citizen."

James P. Roscow *is a business writer and historian. He lives and works in East Hampton, N.Y. This special supplement was produced by Brennan Partners, Inc.*

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AMERICAN MUSEUM OF NATURAL HISTORY

Highlights of the American Museum of Natural History

During its 117-year history, the American Museum of Natural History has amassed an extraordinary collection of over 35 million specimens and artifacts. Many of these objects are on display in the Museum's labyrinth of 38 exhibition halls, while the rest are carefully preserved in storage and are studied by the Museum's large scientific staff, and the worldwide scientific community.

We have compiled a short list of some of the more unusual and famous objects on exhibition in the Museum, with a brief history of each, for those Members who are planning a visit.

The Ahnighito Meteorite. The Arthur Ross Hall of Meteorites contains the largest recovered meteorite in the world. The Ahnighito was first discovered centuries ago by Eskimos living in Greenland, who hammered off pieces of iron to make tools. In the 1890s, the explorer Robert E. Peary persuaded an Eskimo guide to show him the "mountain of iron" and was led to three huge meteorites near Cape York, Greenland. After tremendous difficulties, Peary managed to bring all three back to New York. The two smaller meteorites, called the Woman and the Dog, are also displayed in the hall.

The Willamette Meteorite. The largest meteorite found in the United States is displayed at the opposite end of the Museum, in the Hayden Planetarium. The Willamette weighs only 31,000 pounds (compared to the Ahnighito's 68,000 pounds) and is covered with enormous pits and cavities caused by centuries of rusting in the damp climate of Oregon. The Willamette caused a celebrated lawsuit after it was discovered in 1902. A Welsh miner, Ellis Hughes, stumbled upon it partly buried on a piece of land not far from his house. As a miner, he realized its value. Not wanting to share his find with the landowner, he secretly excavated the meteorite and with the help of his son, labored for months dragging it the three-quarters of a mile to his own property. The Oregon Iron and Steel Company, the owner of the land, learned of the removal of the meteorite, and sued Hughes. The suit went all the way to the State Supreme Court before the judge found in favor of the steel company. The meteorite was later bought for the Museum by Mrs. William Dodge for $20,000; the highest price paid for an item in the Museum's collection up to that time.

The Dinosaur Mummy. In the Museum's great Hall of Late Dinosaurs is a fossil of exceeding rarity. Lying on its back in a glass case is the fossilized mummy of a duck-billed dinosaur, showing the remains of skin, flesh, tendons and bones. This mummy was discovered in 1908 by freelance fossil collector Charles Sternberg in a quarry in Converse County, Wyoming. He wrote of the find, "Shall I ever experience such joy as when I stood in the quarry for the first time, and beheld lying in state the most complete skeleton of an extinct animal I have ever seen, after forty years of experience as a collector! The crowning specimen of my life's work! . . . How wonderful are the works of an Almighty hand!"

The Museum's president, Henry Fairfield Osborn, heard about the find and acquired the specimen just as Sternberg was about to sell it to the British Museum.

Little Finger Nail's Ledger Book. In the Hall of Plains Indians is a ledger book of the type used by the U.S. Cavalry. What is unusual about it is that it is filled with drawings made by a Cheyenne Indian depicting the famous march of the tribe from Indian Territory, where they had been confined to their homelands in Wyoming. Ledger book Indian art had become common during the latter part of the 19th century. The books were often carried into battle. The creator of the drawings, named Little Finger Nail, was killed in a massacre in Wyoming Territory on January 22, 1878. The book, which was believed by the Indian to offer protection in battle, was found strapped to Little Finger Nail's body, pierced by a bullet.

Visitors' Information. In visiting, you may find the following information helpful:

Admission. Admission is on a pay-what-you-wish basis, but visitors must pay something. Admission is free for Museum Members.

Admission to the Hayden Planetarium is separate from the Museum. For Planetarium information call (212) 873-8828.

Naturemax Theater. New York City's largest movie screen—over four stories high—is in the Museum's Naturemax Theater. For prices and showtimes stop by the box office, located at the 77th Street Entrance, or call (212) 496-0900.

Special Events and Programs. Pick up a free copy of *Rotunda* when you enter the Museum to find out about special events. You may also want to visit: the Alexander M. White Natural Science Center, which introduces people to the natural science of New York City; the Frederick H. Leonhardt People Center, which presents music, dance, and lecture-demonstrations of world cultures (weekends only); and the Discovery Room, which has hands-on activities for children. For a free guided tour, stop by any information desk and ask about the Museum Highlights Tours.

American Museum Restaurant. For leisurely dining in a greenhouse setting, the American Museum Restaurant offers fine food and drink. It is located in the basement, near the Central Park West Elevators.

Official Guide to the Museum. To make the most of your visit, purchase the Museum's guidebook. It tells the story of Museum exhibits and provides background material about the dinosaurs, minerals and gems, mammals, birds, anthropology, meteorites, and much, much more.

Discovery Tours. The Museum sponsors tours to remote lands, accompanied by curators and other experts who provide travelers with fascinating information on the flora, fauna, archeology, and peoples of the areas visited.

Membership. Membership in the Museum offers many exciting privileges and benefits, including a subscription to *Natural History*, free admission, special events, and discounts in the Museum Shop and Members' Book Program. Write for free brochure.

Members' Book Program. The Museum offers a wide selection of fine books at discounts to its Members and friends. Subjects include anthropology, archeology, dinosaurs, wildlife art and photography, birds, mammals, history of science, and evolution. Write for free catalog.

For More Information. Write to the departments listed above at: American Museum of Natural History, Central Park West at 79th Street, New York, NY 10024.

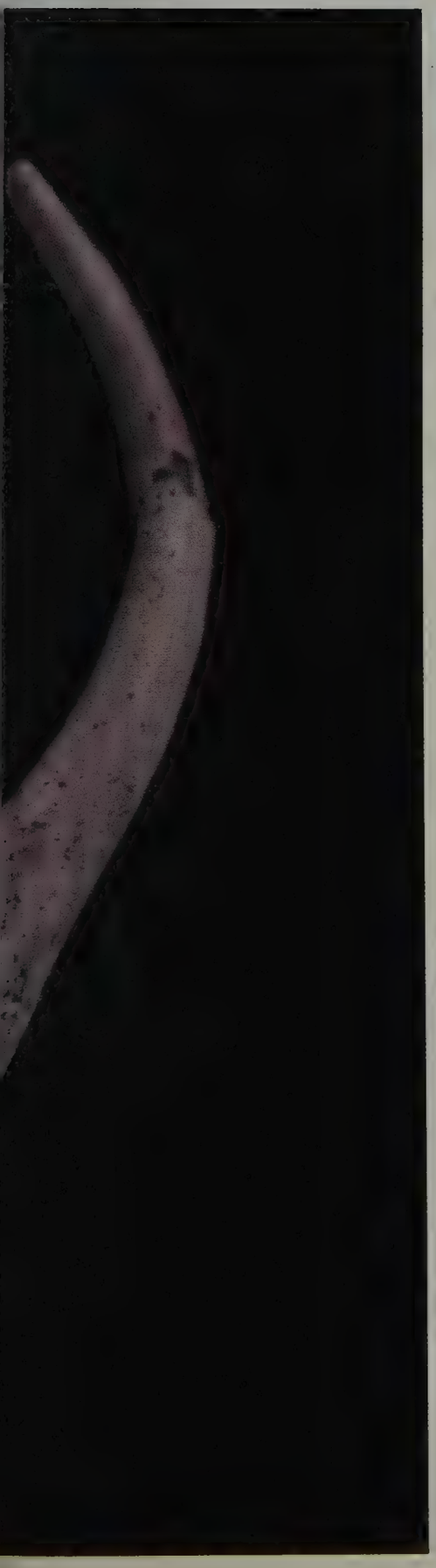
The gastropod below lived during the period of approximately 70 to 60 million years ago. Therefore, this scavenger mollusk survived the great Cretaceous extinction of some 65 million years ago. Low, rocky outcrops on Seymour Island, right, were formed about 45 million years ago. Most of the fossils shown here were found on Seymour.

Townsend P. Dickinson

Fossil Windfall at Antarctica's Edge

An important record of late Cretaceous–early Tertiary life has turned up on a tiny island near Antarctica

by William J. Zinsmeister



William J. Zinsmeister

Filled to bursting with the fossilized remains of ancient plants and animals, the hills of Seymour Island—a rocky speck of land in the Weddell Sea, about thirty miles off the northeastern tip of the Antarctic Peninsula—are a paleontologist's dream. Unlike the rest of the Antarctic region, Seymour Island is free of permanent ice. Its stark, treeless topography evokes the badlands of the American West; and except for the occasional stray penguin and the large, tabular icebergs that drift slowly by on their way to the South Atlantic, there is no sign that the island is so close to the Antarctic. The surprising lack of ice is probably a result of the island's sheltered location, to the lee of the high mountains on the larger surrounding islands. Although severe storms and heavy snow can strike at any time of year, not enough snow accumulates to outlast the sunny days of the austral summer.

The absence of both ice and vegetation, together with the loosely consolidated rock of which the land is composed, has created a uniquely attractive site for paleontologists: fossils are conspicuous, plentiful, and readily weathered out of the rocks. But because of the extremely remote location and the unpredictable nature of the sea ice in the western part of the Weddell Sea, few visits were made to Seymour Island after its discovery in the early 1890s. Reports of the island's marine fossils came from the Swedish South Polar Expedition of 1901–1903, but they gave no inkling of the scope of the scientific treasures contained there.

Modern exploration of the rocks of Seymour began in the early 1970s when Argentina established a permanent research station at the north end of the island. As paleontologists began to appreciate the rich diversity of floral and faunal fossils found in this barren outpost, Seymour Island took on a special importance. Before the exploration of Seymour, what scientists knew about the Antarctic was spotty: they knew, for instance, that a three-mile-thick ice sheet had not always blanketed the mainland; it had once been covered by lush forests and surrounded by shallow subtropical seas that teemed with life. Recent fossil discoveries on the mainland provided a picture of life on Antarctica 300 million years ago, but details of the more recent periods were missing. Findings on Seymour are not only furnishing important information about the history and evolution of the Antarctic, they are also shedding new light on the history of life throughout the Southern Hemisphere

Joe LeMonnier

Seymour Island is not shown in most atlases. Although it is a separate entity, the island is so close to the Antarctic Peninsula that most paleontologists consider it part of Antarctica.

in the last 70 million years—an interval of the earth's history that saw profound geologic and climatic changes.

The sedimentary rocks of Seymour can be divided into two units—a thick sequence of Upper Cretaceous sandstones and siltstones (80 to 65 million years old) restricted to the southern two-thirds of the island and a thinner sequence of Upper Eocene sandstones and shales (45 to 40 million years old) exposed on the sides of a steep mesa at the north end. Finding rocks of this age in Antarctica was fortunate, since they are particularly pertinent to two major geologic events: the final breakup of the once-unified southern continents, with its profound effect on the evolution of all subsequent life-forms, and the extinction of 65 million years ago that marked the close of the Cretaceous period.

The most spectacular discovery so far on Seymour Island was the fossil remains of a primitive marsupial, found in 1981 by Michael Woodburne and Bill Daily, vertebrate paleontologists with the University of California at Riverside. This discovery contributed in part to the solution of a puzzle that has intrigued scientists since Darwin's time, the midnineteenth century: that is, the odd distribution of plants and animals in the Southern Hemisphere. One prime mystery was why marsupials—the mammalian subclass that includes kangaroos, wallabies, and koalas—were found in Australia and South America, but, except for the opossum, not in the Northern Hemisphere. Even more perturbing was that there were so many of these primitive mammals in Australia but none in relatively nearby New Zealand. One thing seemed sure: such large animals would not have been able to cross the stretches of the Pacific that separated Australasia and South America.

In the nineteenth century, attempts to explain these anomalies of range invoked hypothetical land bridges, sinking continents, and floating islands transported by ocean currents or winds. Even as late as the 1950s, considerable controversy surrounded the issue of the origin of marsupials in Australia. Before the Woodburne–Daily discovery on Seymour Island, theories were based on the oldest-known marsupial fossils in North America (which date from 100 million years ago) and on somewhat younger (70 million years old) marsupial fossils from South America. This evidence, and the then-prevalent belief that the continents were stationary, led scientists to postulate that the early marsupials had migrated to Australia by means of a northern route across Alaska and then southward to Asia and Australia. Although no marsupials or marsupial fossils had ever been found in either Alaska or Asia, the north-to-south route seemed plausible because land was almost continuous between North America and Australia.

The beginning of a better answer came in the late 1960s with the acceptance of the theory of continental drift. According to the new theory, about 300 million years ago, all the landmasses of the earth were joined in one supercontinent, which geologists refer to as Pangaea. About 200 million years ago, Pangaea began to break into two enormous landmasses, one in the south known as Gondwana, and the other named Laurasia, in the north. The Gondwana landmass was made up of present-day Africa, Australia, India, and South America, with what is now Antarctica forming the centerpiece. About 50 million years later, Gondwana, too, began to break apart. First Africa split off from the rest; then sometime during the early Cretaceous period (145 to 100 million years ago), India broke off and began a long northward journey across the ocean to its present position as a subcontinent in the Northern Hemisphere. New Zealand broke off as recently as 70 million years ago, but Australia was the last to break off—remaining attached to Antarctica for another 30 million years. It finally separated during the late Eocene epoch about 40 million years ago.

Joe LeMonnier

The Marsupial Trail

The continents may have looked like this about 65 million years ago, following the breakup of the supercontinent of Gondwana. Fossil finds in what is now the northwestern United States and in Antarctica led to the theory that early marsupials migrated some 70 million years ago from North America through South America and across Antarctica to Australia (light areas), all of which were connected in even earlier times, rather than through Asia to Australia. No marsupial fossils have been found in Asia (or other dark areas).

With the recognition that the continents have been changing positions nearly continuously throughout the earth's history and that 65 million years ago Australia was located several thousand miles south of its present position, it became apparent that marsupials could not possibly have migrated to Australia through Asia and that the logical alternative route would have been south from South America to Antarctica and then to Australia. Since New Zealand had already broken off from the larger continent of Gondwana, the reason marsupials never reached that island group also became apparent. Because primitive marsupials were known to exist in South America during the late Cretaceous, the theory of a southern route seemed to be supported by fossil evidence. The final piece of proof needed to validate the southern migration theory came with Seymour Island in 1981. The three jaw fragments of a 40-million-year-old, rodentlike marsupial found by Woodburne and Daily were evidence that the animals had also lived in Antarctica, midway on the journey from South America to Australia.

The study of Seymour Island's fossils has helped solve other distributional puzzles. The southern beech tree, *Nothofagus,* which is found in southern South America, New Zealand, and Australia, but not in Africa, also had a perplexing distribution. The seeds of *Nothofagus* are much too large to be transported by the wind; and the rafting of seeds over long distances by ocean currents is known to be unsuccessful. With acceptance of the notion of a continuous landmass across the southern polar regions of the earth came the hypothesis that present-day stands of southern beech trees must be remnants of an extensive forest that stretched from southern South America to Australasia during the latter part of the Cretaceous period. In 1959, *Nothofagus* pollen was found on the Antarctic mainland, supporting the hypothesis that a forest covered Gondwana at one time. The discovery of *Nothofagus* leaves on Seymour Island confirmed the presence of the southern beech in Antarctica.

The examination of Antarctic fossils also presents the biogeographer with a unique opportunity to study evolutionary processes resulting from the breakup of the southern continents. After their initial separation from Gondwana, Australia and New Zealand drifted slowly northward into progressively warmer regions, while South America remained at nearly the same latitude, although it gradually moved in a westerly direction. Antarctica was stationary during this period. And because it scarcely moved for 50 million years, it can be used as a standard against which to compare the faunal and floral changes on the other continents.

The marine mollusks that I have been studying on Seymour Island—such as the large clam *Lahillia* and the strombidlike gastropod *Struthioptera*, which are known from the late Cretaceous and early Tertiary of South America and Australia—indicate that prior to the breakup of Gondwana, the Southern Hemisphere contained similar forms of life that ranged from southern South America along the southern margin of the Pacific to Australia. As the southern continents gradually drifted away from Antarctica, however, their animal and plant life became genetically isolated, and new species began to evolve.

The northward drift of Australia and New Zealand brought the two continents into warmer regions of the southwestern Pacific. The groups of animals that had originally evolved nearer the pole were forced to adapt to a rapidly warming climate. At the same time, an element of competition was introduced: Species from the subtropical regions of the southwestern Pacific began to migrate into New Zealand and Australia. The combined effect resulted in the extinction, in Australia and New Zealand, of most of the plants and animals that had originated in early

Individuals from the group to which the starfish, below, belongs had never been seen before in fossil form. This specimen was found in 1984. Relatives of this ancient group which dates back about 40 million years, are alive today in all temperate sea waters.

Townsend P. Dickinson

Two California paleontologists discovered the fossil remains of the lower jaw of a primitive marsupial, below, on Seymour in 1981. The find was the first recovery of a mammalian fossil in the Antarctic region and gave support to a new theory about the migratory patterns of early marsupials.

Michael O. Woodburne

Gondwana. Many of the marine mollusks, such as *Lahillia* and *Struthioptera*, common in the sea surrounding Australia and New Zealand during the late Cretaceous and early Tertiary, disappeared.

In the meantime, Antarctica remained over the South Pole and gradually cooled. Now isolated from the other southern continents, it was beyond the reach of subtropical species of plants and animals that were invading New Zealand and Australia. As a consequence, while dramatic evolutionary changes were taking place in Australasia, the fauna in Antarctica hardly changed, and most of the early Gondwana species such as *Lahillia* and *Struthioptera* survived there. Eventually, long after their extinction elsewhere in the southern half of the earth, the early Gondwana species were wiped out by the gradual cooling on the Antarctic mainland.

New insights into the worldwide extinction that occurred about 65 million years ago are also being gained from research on Seymour Island. Throughout most of the world at that crucial time, many groups of plants and animals—from the giant reptiles, such as the dinosaurs, to the intricately shelled sea creatures, the ammonites, to the microscopic, one-celled marine plants—suddenly became extinct. One recently proposed hypothesis attributes this major extinction to a collision of an asteroid with the earth. Nearly all of our information about this period had come from geologic studies in North America and Europe. The fossil sequences on Seymour Island provided the first opportunity to study the late Cretaceous extinction in the polar regions.

The mollusk fossils that I have been examining indicate that, although many species of clams and snails became extinct on Seymour Island at the end of the Cretaceous, a number of them—including the clam *Lahillia* and the gastropod *Perissoptera*—survived. Rosemary Askin, a micropaleontologist at the Colorado School of Mines, who has been studying the marine dinoflagellates (one-celled planktonic marine plants) and pollen from terrestrial plants, has found that the wholesale extinctions that occurred in Europe and North America were not in evidence at the extreme southern latitudes. Information from Seymour Island about the extinction indicates that, whatever the cause, the result was not as severe in the southern regions as in other areas of the earth. At present, our data do not favor any particular theory concerning the extinction of the dinosaurs. We hope that future work on Seymour Island will shed new light on this great mystery.

Ferns like the fossil below grew on Antarctica about 40 million years ago, when the now-barren continent was covered with lush forests. The crinoid, right, is called a living fossil because its descendants are common bottom dwellers in today's deep seas. Until this fossil was found, examples of this group of crinoids were missing from the fossil record.

Both photographs by Townsend P. Dickinson

The study of marine invertebrate fossils at the north end of Seymour Island by Rodney Feldmann, of Kent State University, and me has resulted in the unexpected discovery that some modern marine creatures that were thought to have evolved only since the last Ice Age (about 10,000 years ago) have a fossil record extending back to late Eocene times—40 million years ago! Among them are a starfish of the genus *Zoroaster*, the crinoid *Metacrinus*, the crab *Lyreidus*, the clam *Gaimardia*, and the gastropod *Perissodonta*. Before such discoveries on Seymour Island, it was thought that most evolution occurred in the tropics and subtropics and that new forms then migrated southward into the polar areas. We now know that many types of marine organisms were actively evolving in the Antarctic during the early Tertiary and that many of them originated in far-southern waters and migrated northward only relatively recently.

The occurrence of some of these invertebrates—the starfishes, crinoids, and crabs, for example—on Seymour Island in the Eocene also casts new light on the origins of life in the deep sea. Before their discovery on Seymour, they were known only as contemporary forms living in the deep, cold waters of the Pacific Ocean and the Gulf of Mexico. Their presence in shallow-water Eocene deposits on Seymour indicates they may have first evolved in the temperate, shallow seas around Antarctica and subsequently migrated into deeper waters when the oceans began to cool about 30 million years ago.

I first went to Seymour Island in 1975 and returned on three more expeditions in the 1980s. On all those trips new and important discoveries were made almost every day. Two days before the end of the 1985 expedition, I found a nearly complete skeleton of a pleiosaur (a large Cretaceous marine reptile that reached a length of nearly forty feet) exposed on the side of a small hill. Because of poor weather, we were unable to collect this remarkably well-preserved skeleton, but we hope to get it on the next trip.

Now we are about to leave for Seymour Island once more. I feel confident that the fossil deposits on the island will continue to shed new light on the origin and distribution of the flora and fauna of the Southern Hemisphere and also on the role played by Antarctica in the evolution of life. Seymour Island has now become a paleontological "Rosetta stone" for our understanding of the history of life in the Southern Hemisphere. □

Sex and Gluttony on Delaware Bay

The annual influx of egg-laying horseshoe crabs attracts hordes of hungry, northbound shorebirds

by J. P. Myers

Late in May every year, sandy beaches along Delaware Bay in southern New Jersey and Delaware host unparalleled scenes of chaos, sex, and gluttony. These beaches lie some forty miles from the resort caldron of Atlantic City, but their intense activity has a source remote from the gala allure of casinos. They writhe instead with breeding horseshoe crabs and gluttonous migratory shorebirds.

From the depths of Delaware Bay, a million or more horseshoe crabs emerge to breed on the beaches and lay their eggs near the high-tide line. From South America comes a ravenous onslaught of migratory shorebirds bent upon consuming the crabs' eggs and using the nutrients to fuel the next leg of their trip to arctic nesting grounds. The confluence of these two forces—crabs and birds—transforms Delaware Bay each spring from a site of tra quillity to one of pandemonium. This re ict scene from epochs past underpins vast shorebird migration system.

Horseshoe crabs begin their migratio to the beaches in early spring after a wi ter spent in the bottom zone, or benthos, Delaware Bay and the nearby waters the Atlantic. Fishermen know the anima are on the move because by March th

rabs become ensnared in nets set for veakfish and menhaden. By early May he assault on the beaches begins.

Moving upward from the water, horse-hoe crabs (which are not true crabs, but iphosurans) resemble armor-clad tanks; heir heavy outer carapaces protect them nd their soon-to-be-laid eggs from numer-us predators. At least eleven species of nigratory shorebirds, three species of gulls, song sparrows, cowbirds, common grackles, mourning doves, house finches, and even starlings, house sparrows, and pigeons feed upon accessible eggs. But the list is not limited to birds. Nearby waters roil with small fish picking off eggs washed into the bay, while mollusks scavenge on the nearshore bottom. Many egg clusters are parasitized by a nematode worm, probably transferred from mother to egg at the time of laying. Mammals, too, join in the feast. Raccoon and fox tracks can be found along the beaches at dawn, and even mole mounds can be seen marking a trail from the dunes to the upper reaches of the intertidal zone where the eggs lie buried.

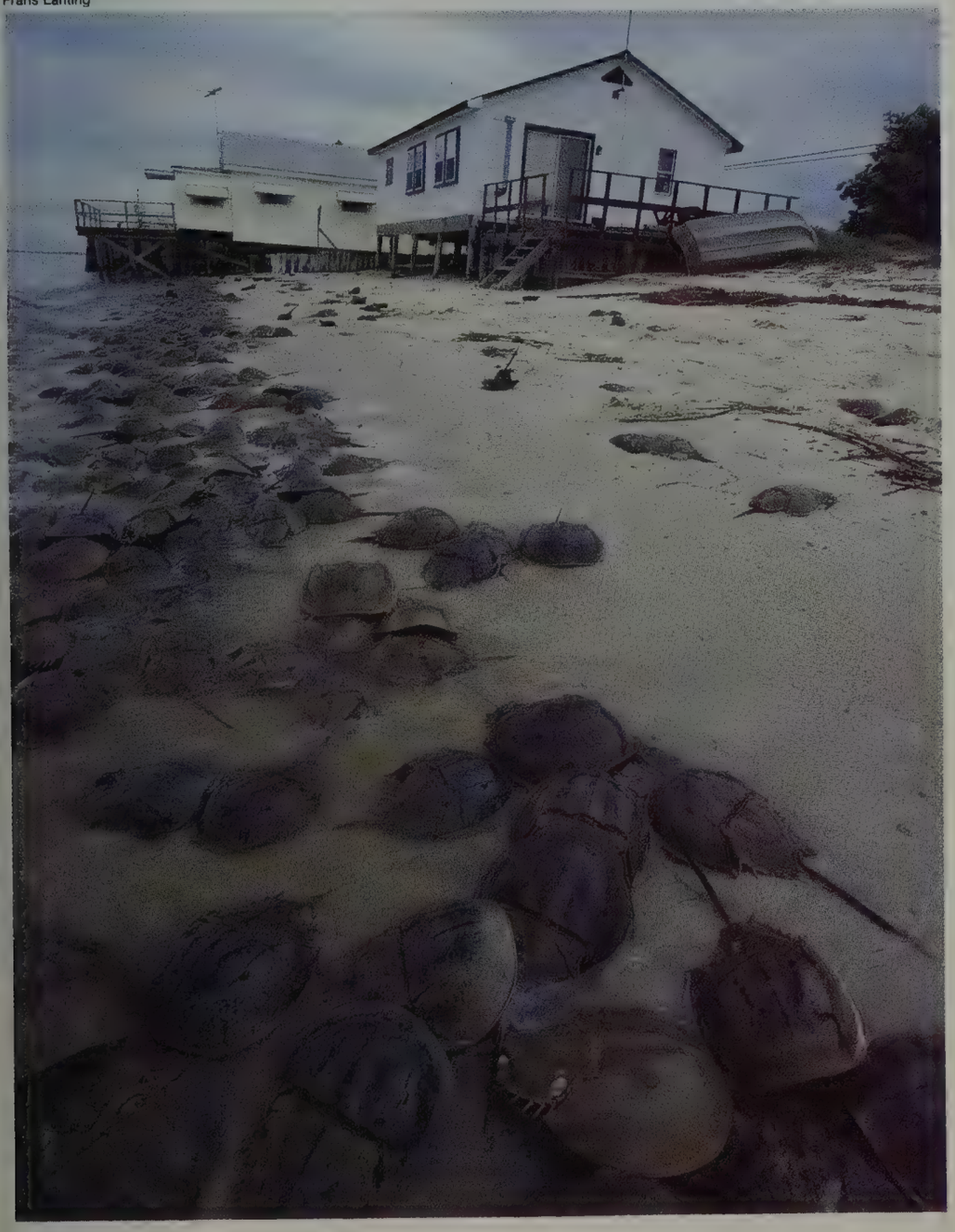
Nesting to the east in marshes adjacent to the Atlantic, laughing gulls fly by the thousands to dine at the best crab beaches.

Tidal flat, Delaware Bay
Frans Lanting

Brock P. Kent

After migrating for weeks, horseshoe crabs reach their breeding grounds along Delaware Bay early in May. Males, the smaller sex, are the first to beach. When the egg-laden females arrive at high tide, males vie for the chance to fertilize the eggs, forming competitive clumps along the shoreline, left. The mating ritual, part of the crabs' life cycle for more than 300 million years, is now performed, below, within a few feet of beach houses.

Frans Lanting



They displace the smaller shorebirds such as sanderlings and semipalmated sandpipers, which for their part avoid landing in dense aggregations of large, aggressive, and hungry gulls. Ruddy turnstones don't entirely shun gulls, but they usually stay somewhat up the beach, away from the water's edge and feeding gulls. Egg consumers themselves attract predators. Peregrine falcons feed upon the shorebirds. Terns, egrets, and herons pursue the fishes, as do larger fishes.

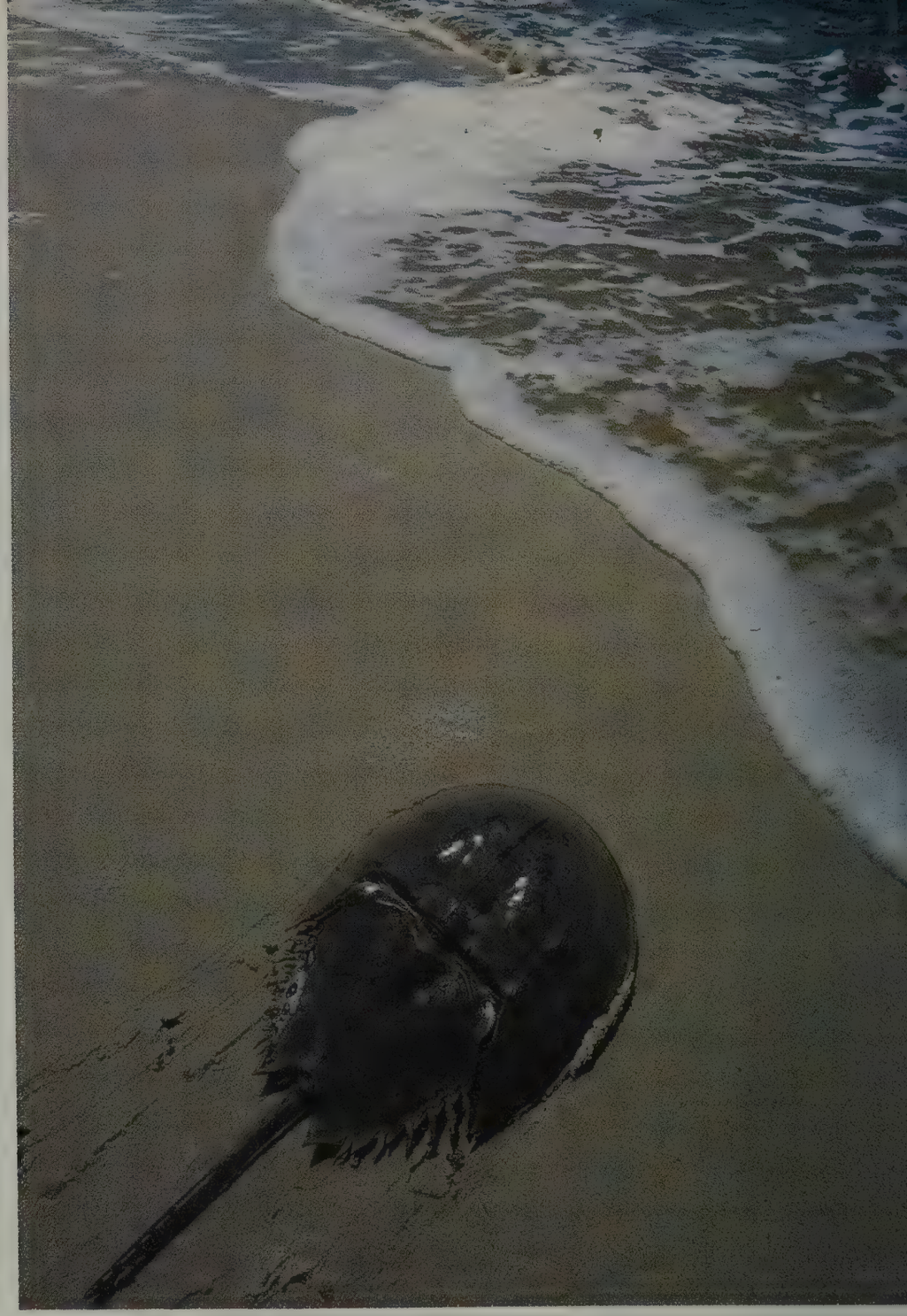
Most human attacks on horseshoe crabs come with the destructive aggression of pubescent boys, but people have long exploited the crabs and their eggs. In the last century, horseshoe crabs were common sources of eel bait and pig food. Neurophysiologists have founded pivotal studies of light reception in simple eyes on work with horseshoe crabs. And now a small, growing industry extracts a compound from the horseshoe crab's blood to use as an alternative to a rabbit-serum-based medical test. None of these human actions, however, has threatened horseshoe crab populations. Wildlife regulations stipulate that once bled for the compound, crabs must be returned alive to the beach from which they were garnered.

Of far greater danger are the incessant advances of coastal land development and "reclamation" that replace breeding habitat with bulkheads or rip-rap to retard wave erosion. These structures may temporarily stabilize the shoreline for beach houses, but they usually alter beach topography so greatly that crabs can no longer lay their eggs there.

Large-scale traffic of petrochemicals in Delaware Bay is another source of concern. The lower bay is one of the world's largest areas of oil transfer from ocean-going vessels to coastal barges and pipelines. The cities of Wilmington and Philadelphia, along with a slew of refineries in the area, make the upper bay the second largest petrochemical port in the United States. A major spill, coupled with strong southerly winds—common in late May—could inundate the critical beaches with a devastating bouillabaisse of crabs, eggs, and oil.

Far from being true crabs, horseshoe crabs (*Limulus polyphemus*) are ancient arthropods—much closer to scorpions, spiders, and other arachnids than to blue, dungeness, or fiddler crabs. (Horseshoe crabs are nothing if not persistent. Fossil *Limulus* from 300 million years ago appear much as do Delaware Bay residents today.) Superficially these crabs resemble fossil trilobites. Their link to the arachnids rests on various anatomical features, in particular their "book gills." These gills are proposed by some scientists as the ancestral form and by others as the derived form of the terrestrial arachnid's "book lung," which looks like pages in a book. Resemblances between *Limulus* and arachnids are distant enough, however, to keep the relationships in debate and to secure for horseshoe crabs their own order, the Xiphosura.

Each adult crab spans twenty inches or more, including carapace and sharp, rigid tail. The football-sized carapace of adult males is noticeably smaller than that of females. Males possess a pair of distinct appendages, called pedipalps, located just



behind the mouth and designed to grasp the female's carapace during mating. Once in place, the pedipalps' tenacious hold allows most mating males to fend off competitors trying to dislodge them.

Before high tide on a day during the crab-breeding season in May, a few signs along the beach foretell what is about to happen. Carapaces from tides past lie above the water baking in the sun or filling with rain. While these crabs are in various stages of dying, such is not the necessary or even the usual fate of horseshoe crabs after breeding. Most return to the bay to await another season. But ironically, for an organism so persistent in evolutionary time, a horseshoe crab cannot right itself if flipped by the surf. This happens to many crabs in each tide cycle and only a few of these will be righted by wave action in a later tide. Perhaps to compensate for this curious inability, a horseshoe crab can withstand many days of exposure as long as its book lungs remain damp.

Male crabs appear first as the tide starts to recede. They emerge from the bay to line the water's edge in a band several crabs wide, a crab or two high, and continuous for miles along beaches of suitable habitat. More than 10,000 can pack into just half a mile, all waiting for the females to emerge and crawl up the beach toward a suitable egg-laying site. Each male vies to be the one to fertilize a female's eggs.

Females begin rising out of the bay within a hour of the turning high tide. As the females appear, the solid line of males breaks down into clumps of ten to fifteen or more males, each individual attempting to clasp a female's carapace with its pedipalps. Males scramble into heaps, male atop male atop female, washed to and fro by the surf. Sticking vertically out of the water, the tails wave back and forth like dancers in a chorus line. This is the moment when some crabs are flipped.

When a male succeeds in attaching to a female, they inch up the beach together, the male holding on from behind. Both male and female must leave the water to mate. The female digs a hole, and then, as she lays her eggs, the male fertilizes them. Together they cover the egg mass with sand. Tides permitting, the pair then return to the water.

A single female may lay up to 80,000 eggs. Each egg is round, approximately a few hundredths of an inch in diameter, and may range from olive green to brown. The female divides her clutch into a number of clumps, each a tightly bundled mass from one-half inch to four inches across. Perhaps to confuse birds probing for eggs with their bills, the female mixes pebbles and bits of debris within each clump. After they are buried, the clumps of eggs lie clustered in a nest some two to eight inches beneath the surface. Laying activity is so dense that by season's peak, some beaches will have as many as fifty nests in each square yard of sand near the high-tide line.

Now the shorebirds begin to arrive. From the coasts of Brazil, Patagonia, and Tierra del Fuego, from desert beaches of Chile and Peru, and from mud flats in Suriname, Venezuela, and the Guyanas, shorebirds have flown days on end to reach these egg-strewn beaches on Delaware Bay. Some birds arrive in early May. The numbers rocket upward during midmonth and usually peak between May 18 and 24 but in some years as late as May 28. Then, even more rapidly than they rise, the numbers crash, falling from a million to a few tens of thousands within a two- to three-day span. By the end of the first week of June, few birds remain.

Why the rush? Breeding grounds beckon in the high Arctic of Canada. There the migrants face stiff competition for breeding territories and only a few weeks in which to mate, nest, raise young, and prepare for southward departure. No early bird in the Arctic gets a worm—

Horseshoe crabs return to the sea, left, after the fertilized eggs (up to 80,000 per female) have been laid in clusters beneath the sand. Amid stranded dead and dying crabs, ruddy turnstones, below, plumb the wet sand for eggs. Turnstones aggressively defend their "digs" against would-be usurpers.

Geoff LeBaron; VIREO

they're not part of the Arctic menu—but no late bird will breed successfully.

No one has made a precise census of the total numbers passing through Delaware Bay during spring migration—there are too many birds and too much movement to yield to traditional methods. But enough is known to place the total at between 500,000 and 1,500,000 shorebirds within the bay in the latter half of May. Red knots, sanderlings, ruddy turnstones, semipalmated sandpipers, and dunlins predominate. Among these can also be found least sandpipers, willets, short-billed dowitchers, semipalmated plovers, black-bellied plovers, and even a few white-rumped sandpipers. Several beaches within the bay boast extraordinary concentrations of shorebirds during the peak season. Reed's Beach, Moore's Beach, and Norbury's Landing can each accommodate more than 100,000 shorebirds at one time. In late May 1985, a single flock of semipalmated sandpipers at Moore's Beach, New Jersey, contained an estimated 250,000 birds.

Sanderlings concentrate near the bay's opening to the Atlantic Ocean, particularly at Norbury's Landing. North and inland away from the opening to the Atlantic, ruddy turnstones and red knots replace the sanderlings, reaching their peak numbers in the area around Reed's Beach. Still farther inland, semipalmated sandpipers dominate. Even with these general trends, large numbers of each species can be seen along the bay shore from Villa north to Fortescue, New Jersey. Important concentrations also occur on the western, Delaware side of the bay.

The shorebirds spend their daylight hours eating horseshoe crab eggs, resting, and preening. While foraging, they switch between devouring fresh egg clusters lost by female crabs moving onto the beach, plucking single eggs out of the waves, and probing or digging for eggs buried above the water line. For reasons yet unknown, few birds feed on the eggs windrowed in masses along the water's edge.

Eggs beneath the surface often lie beyond the probes of even sandpipers with their long bills. Turnstones circumvent this by digging. Gradually they pockmark the wet sand with holes two to four inches deep. The turnstones' holes become the foci of considerable aggression. Turnstones bump and shove, squabbling over one hole then another. Watched closely, their aggression is curiously inconsistent; it can rise to a bout of intense jabs only to end with both attacker and defender scurrying off separately to other holes. More than half the time, each occupant has its back feathers raised and tail lowered, presumably a display to deter potential usurpers. If one does attempt a coup, then defender and attacker will rise together in upright postures, jabbing each other's chests and chattering aggressively. Sometimes the original occupant prevails and remains with its possession; sometimes it is supplanted. One predictor of success is crown color. Duller-crowned birds almost never resist the attack of a turnstone with bright, highly contrasting head markings. The bout may result in new ownership of the hole or the defender may chase the intruder off, sometimes running after it several yards before returning to the hole.

Smaller shorebirds such as sanderlings and semipalmated sandpipers never supplant turnstones from holes. But if turnstones abandon a hole for more than a minute or so, the smaller birds will move in. The sanderlings often adopt the holes as their own and subsequently defend them against other sanderlings. Semipalmated sandpipers almost never display aggression and several of these small birds may forage simultaneously in the same hole. The aggression displayed by many species in the midst of a seemingly plentiful food supply is one of the phenomena being investigated by field biologists.

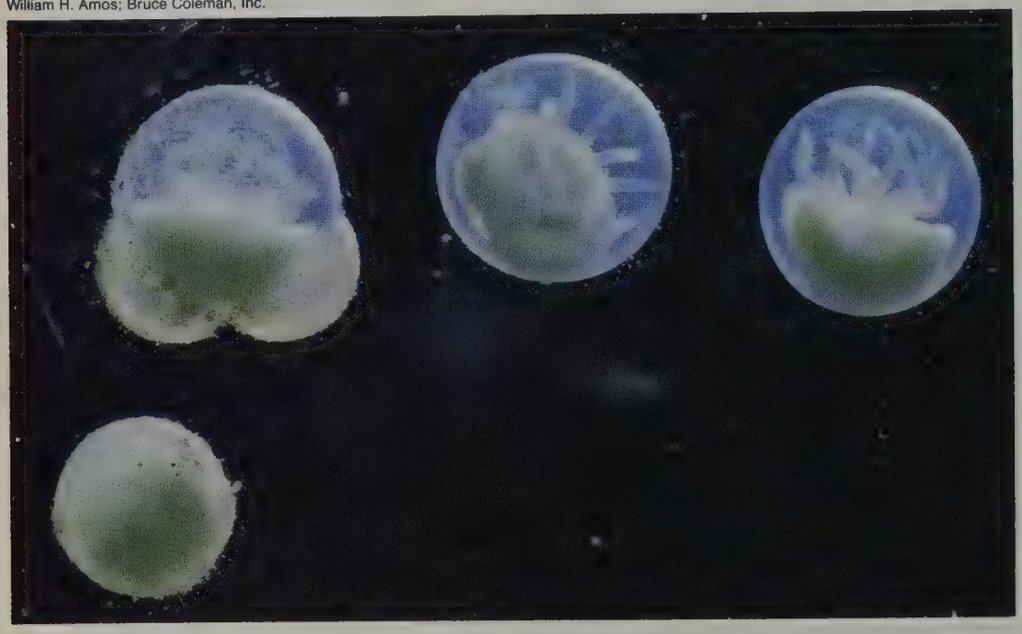
Ruddy turnstones frequently yield to laughing gulls moving about the area. These gulls appear to monitor the successes and failures of shorebirds foraging in different holes. If a turnstone tarries too long within a hole—something likely if the spot is particularly rich—then the gull moves in. The turnstone makes no attempt to resist, slipping off to find another hole to exploit.

As dusk approaches, birds abandon the bay beaches and fly eastward toward the great tidal marshes along the outer shore and onto the outer shore itself. For some birds feeding far up the bay, this flight may entail twenty or thirty miles. Why they deem the bay shore unsuitable at night is unknown. On those nights when the tide is low, some species such as red knots roost in the marshes, while others such as sanderlings move to the outer beach. But on nights of high tides, they all are forced out to the few remaining unde-

Frans Lanting

Only about one millimeter in diameter, single horseshoe crab eggs, below, supply a minute amount of food energy, but shorebirds consume enormous numbers of them. By gorging on eggs, a bird may double its weight in two weeks. Laughing gulls and ruddy turnstones, right, shoulder each other while feeding on a stretch of beach. The large, contentious gulls supplant turnstones from productive sites. Small shorebirds such as sanderlings and semipalmated sandpipers stay clear of the gulls.

William H. Amos; Bruce Coleman, Inc.



veloped stretches of sandy ocean beach. Given the extensive development of condominium, resort, and beach-front homes that has occurred along New Jersey's Atlantic shore, the birds have few choices left. On high-tide nights, roosts can swell to 100,000 birds or more, all packed into a few hundred yards of beach. The scene as they gather at dusk is chaotic—knots and turnstones, sanderlings and sandpipers, all swirling as they arrive in groups of from ten to as many as three hundred from the bay. Their noise overlays the calls of breeding least terns, American oystercatchers, piping plovers, and black skimmers.

Shorebirds arriving from South America have depleted their stores of energy in several days of nonstop flight. The crab eggs offer new sustenance. Each small egg contains only a minuscule quantum of energy, about 0.035 kilojoules (KJ), by itself, hardly a powerhouse. Yet a single egg's slim energetic value is almost irrelevant, for there are so many of them. Whole stretches of beach are covered with rafts of wave-washed eggs. In a few places where currents converge, the windrows pile up to a thickness of two feet, and while these surface eggs are wasted, many times more lie buried beneath the sand.

During their brief stay in the bay, the shorebirds gorge ravenously on eggs. Some birds literally double their weight from fat accumulated. For example, a sanderling depleted of fat after migrating north to the bay might weight 45 to 50 grams. By late May that same individual could stumble onto the scales at 100 grams. To what does this translate in egg consumption?

To increase in weight by 1 gram of fat, a bird must eat enough eggs to cover its daily energy expenditure—about 62 KJ for a 50-gram (lean weight) bird—plus enough to pay for laying down the gram of fat. The latter cost includes three variables: the value of the fat itself (39 KJ per gram); the efficiency of taking ingested energy and making that available for metabolic work (about 80 percent); and the metabolic cost of converting energy digested to stored fat (about 0.5 KJ for each KJ stored). Thus a sanderling reaching the bay on May 15 at a lean weight of 50 grams and departing on May 28 at 100 grams must have eaten nearly 135,000 eggs in that fourteen-day episode. This would require consuming an average of one egg every five seconds during fourteen hours of foraging each day, amounting to roughly two-thirds of the bird's lean weight each day. Fifty thousand sanderlings—a conservative estimate of the number of birds present—would consume almost six billion eggs, weighing a total of twenty-seven tons, in fourteen days.

Delaware Bay is unquestionably the largest spring staging site for shorebirds in eastern North America. No other spot comes close. Together with the Copper River Delta in Alaska, Gray's Harbor in Washington, the Bay of Fundy, and Cheyenne Bottoms, Kansas, each of which harbors hundreds of thousands to millions of shorebirds during northbound or southbound migrations, Delaware Bay underpins the entire migration system of New World shorebirds. Without these sites, the stupendous migrations undertaken by North America's shorebirds would be impossible.

Staging sites—separated by vast expanses devoid of suitable foraging sites—work as links in a chain connecting wintering areas with breeding grounds. Studies of food and habitat availability indicate that shorebirds have no alternative but to gather in these limited areas. Even where alternative wetlands can be found, special characteristics of single sites, such as the

horseshoe crabs in Delaware Bay, render them uniquely able to support the energetic demands of large numbers of birds concentrated in a migration stopover. As a result, major sites are used year after year, both by individuals within their own lifetime as well as by populations over generations. As long ago as 1813, Alexander Wilson published observations of the horseshoe crabs and ruddy turnstones on Delaware Bay. He noted: "This spawn [the crabs' eggs] may sometimes be seen lying in hollows and eddies in bushels; while the Snipes and Sandpipers, particularly the Turn-stone, are hovering about, feasting on the delicious fare." These are our earliest recorded observations, but surely the scene in Delaware Bay is an ancient one.

The health of entire animal populations depends upon the continuing ability of Delaware Bay and other key staging sites to support migratory birds. Degrading or removing a site risks undermining the migration system itself. Large proportions of entire populations funnel through the principal staging site of North America. Some 80 percent of the *rufa* race of red knots depends upon horseshoe crab eggs in Delaware Bay. Comparable portions of New World Atlantic populations of sanderlings and ruddy turnstones do as well. On the Pacific coast, nearly 100 percent of western sandpipers and dunlins use the Copper River Delta staging site.

These concentrations of birds are thereby of fundamental conservation significance. None of these shorebirds is endangered in the classic sense—numerically common species usually are not at major risk. But funneling through staging sites breaks the normal link between a species' abundance and its immunity to extinction. Typically, large populations are considered immune by virtue of the exceedingly small probability that all members of a population will fail to replace themselves in the same period. This interpretation, however, assumes that the likelihood of failure for each member of the population is independent of that for all others. Such is not the case where such large fractions of entire populations gather at the same place at the same time, particularly in habitats as prized by birds and as threatened by man as are coastal wetlands.

The scene on Delaware Bay during May is more than a spectacular natural history event, for the eggs underwrite the New World migration system of Atlantic shorebirds. The state of New Jersey, through its Division of Fish, Game, and Wildlife, is now implementing long-term conservation plans for protecting habitat critical to horseshoe crabs and birds. These plans include purchase of key beaches and a management program to minimize harassment during migration

Marooned at low tide and unable to right itself, an overturned horseshoe crab, below, lies helpless after mating. Reenergized after frenzied feeding, the semipalmated sandpipers, right, will resume their migration north to breed.

Both photographs by Frans Lanting

season. The governors of Delaware and New Jersey have now signed a resolution proclaiming the lower estuary of Delaware Bay a reserve for shorebird conservation. The next step for local groups, in conjunction with the World Wildlife Fund-U.S. and the International Association of Fish and Wildlife Agencies, will be to coordinate work with other sites in the chain used by migratory shorebirds around the hemisphere, to link them all in a network of sister-reserves for shorebird protection. This will be a landmark step in international wildlife conservation.

Delaware Bay from May 20 to June 2 evokes prehistoric epochs—horseshoe crabs from the depths, bird hordes from afar. How it has persisted through these centuries of human population growth defies reason. Whether it will continue depends upon the effectiveness of actions under way now, in Delaware Bay itself as well as at other critical spots along the migration pathways of the birds. But at least for the moment, if one is careful during evenings as the roosts gather, if one ignores some golden arches and a condo or two or ten along the nearby Jersey shore, (scenes of other forms of chaos, sex, and gluttony), there remain sites where one can sweep the horizon with binoculars and see little else but the swirl of bird and crab and twilight. □

The Natural History of AIDS

The disease may have existed in isolated humans for thousands of years

by Matthew Allen Gonda

In 1984, a previously unknown virus was isolated from human blood. Named HTLV-III (human T-cell lymphotropic virus type III), the virus selectively attacked a specific group of white blood cells crucial to the body's immune response. Soon generally recognized as the causative agent of acquired immunodeficiency syndrome, or AIDS, the virus was later discovered to have an affinity for infecting cells of the brain as well.

Although the AIDS disease process has proved to be enormously complex and often baffling—there is no complete parallel for it among the other viral diseases of humans—we have learned a great deal about the virus's molecular biology and structure in a very short time. Structurally and biochemically, HTLV-III belongs to the retrovirus family, a unique subgroup of viruses found not only in humans but also in many animals, from reptiles to primates. Like other viruses, retroviruses don't always cause disease in their hosts.

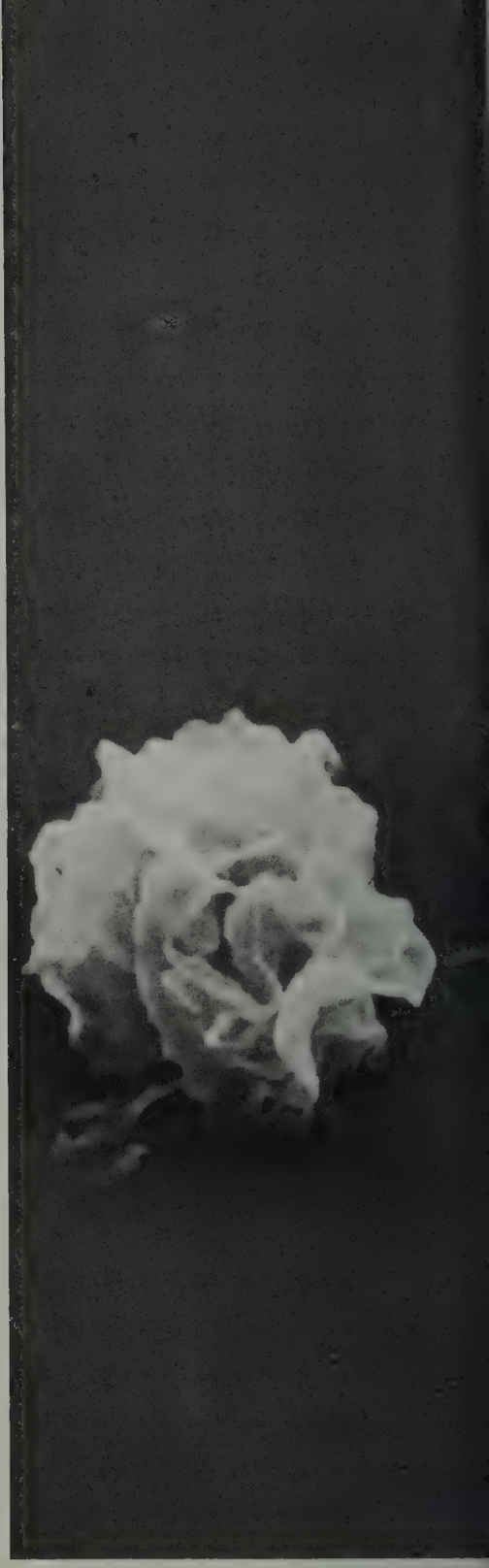
Also like other viruses, retroviruses are not really living organisms. Lacking the machinery and the energy-generating capabilities to manufacture progeny, they are perhaps best described as infectious chemicals made up of a sticky protein coat encapsulating a genome (the DNA or RNA blueprint for constructing more viruses). Incapable of growth and division on their own, viruses exploit the cells of living organisms to perform these functions for them. Infection occurs when, via highly specific receptors on its protein coat, a virus attaches itself to and penetrates a susceptible cell. Once inside, it is read and reproduced by the host's manufacturing machinery. Sometimes the cell is killed during virus replication; but before its demise, it has released a new generation of viruses into the host's system.

Retroviruses have evolved a particularly effective variation on this parasitic theme. Unusual because their genomes are composed of RNA (in most living things, including most viruses, genomes are composed of DNA), retroviruses also possess a gene for a unique enzyme, reverse transcriptase. When the retrovirus attaches itself to and penetrates a cell, reverse transcriptase transcribes the retrovirus's genetic information from RNA into DNA. The host, often perceiving this new DNA to be its own genetic material, integrates it into its own chromosomes. Once in this new habitat, the retrovirus may be reproduced or it may remain dormant for weeks, months, or even years. The virus stays in the chromosomes for the life of the cell, that is, until the cell has been killed by the infection, eliminated by the immune system, or removed after senescence. The association is permanent; every time host cells reproduce, they also reproduce retrovirus DNA, even in the absence of new virus.

Some mouse and chicken retroviruses have assured themselves of even longer relationships with their hosts. Because in a past event they infected and were integrated into the host's germ cells (that is, sperm and egg or their precursor cells), they are now automatically transmitted to the next generation of host animals without an infectious cycle. There are no known methods of eliminating these so-called endogenous viruses.

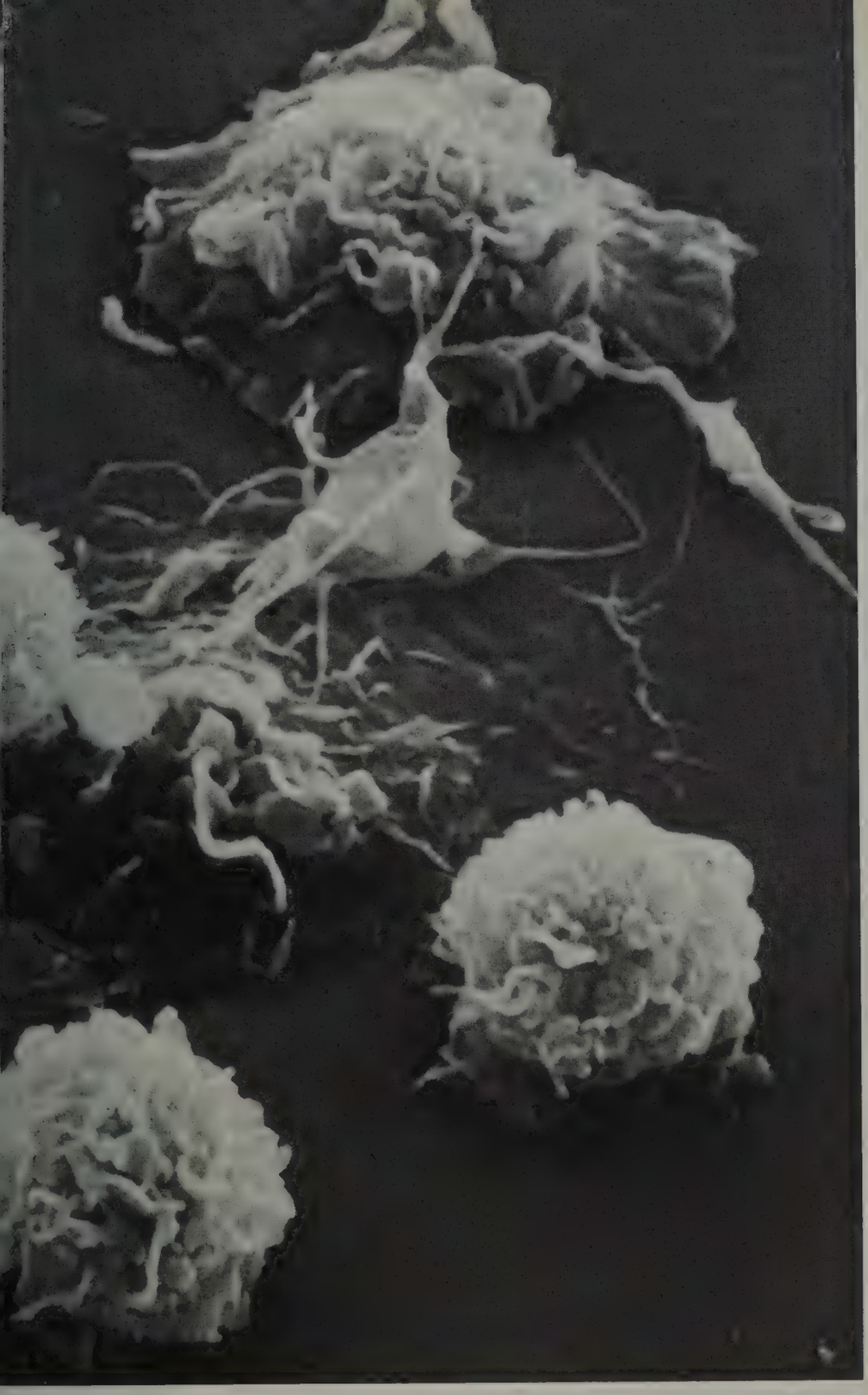
Other retroviruses are exogenous—that is, acquired from the outside. The AIDS virus, passed from person to person (or from pregnant woman to fetus) via infected blood or body fluids, is of this type. Exogenous or endogenous, however, retrovirus infections have one feature in common; infected individuals remain infected (though not necessarily ill) for life.

Before the discovery of the AIDS virus, only two other retroviruses had ever been isolated in human beings. These—the human T-cell leukemia viruses, HTLV-I and II—belong to the oncovirus subfamily of retroviruses, so called because they are oncogenic (tumor producing in their host). Like the AIDS virus, they attack T-4 lymphocytes, the white blood cells that begin the immune reaction. The question therefore arose early as to whether the AIDS virus was also an oncovirus. At first, the idea seemed plausible, because of the properties shared with the the leukemia viruses, the most prominent of which was their affinity for T-cells. In addition, the AIDS virus was suspected of causing



Kaposi's sarcoma, a rare cancer of the skin's blood vessels, from which many AIDS victims suffer. Further investigation, however, made it clear that HTLV-III did not directly cause Kaposi's sarcoma. Rather, the tumors were arising opportunistically because of the underlying immune deficiency, just as they do in organ-transplant patients who are given immunosuppressive drugs.

If the AIDS virus was not an oncovirus, what was it? Investigators began to look for similarities in the two other known retrovirus subfamilies—the lentiviruses and the spumiviruses. (There was also the possibility that it belonged to a new group of retroviruses not previously identified.)



Human blood cells, magnified about 4,000 times in a scanning electron micrograph. AIDS virus infects several kinds of white cells, including the T-4 lymphocytes (center), macrophages (top), and monocytes (bottom tier).
Kunio Nagashima and Matthew Gonda

The spumiviruses, or foamy viruses, although they had not been thoroughly studied, were ruled out quickly; they were not known to cause disease, and structurally, they differed sharply from both the leukemia viruses and from the AIDS virus.

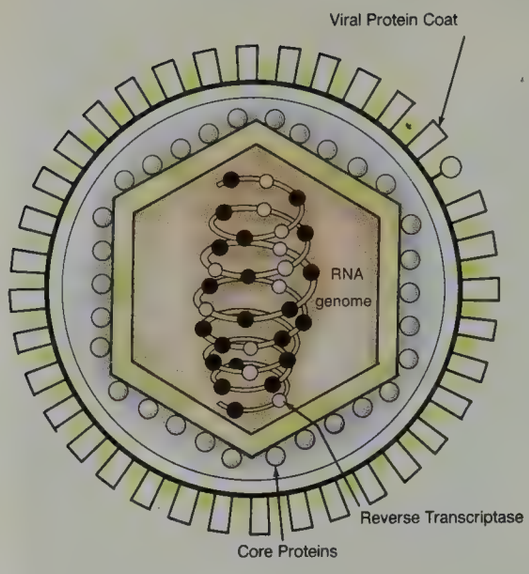
Important clues to the identity of the virus were already apparent, however. Most important was that the AIDS virus did not cause cancerous proliferations but instead brought about cell-killing (cytolytic) events. This cytolytic propensity is one of several distinguishing properties of the lentiviruses. Called "slow" viruses for their slow but persistent rate of replication, the lentiviruses eventually induce debilitating diseases, although years may pass between the initial infection and the onset of symptoms. Since the AIDS virus also is associated with the slow evolution of a lethal debilitating disease, this was a second family resemblance. Firmer evidence came from electron microscope pictures; HTLV-III strikingly resembled the visna virus, a lentivirus that infects sheep.

Lentiviruses had been isolated from a variety of ungulates—sheep, goats, horses, cows—that have been closely associated with humans for thousands of years. Visna virus—grouped with maedi and progressive pneumonia viruses, two related retroviruses of sheep—was the first lentivirus to be isolated and the first to be intensively studied. *Visna,* the Icelandic word for "wasting," was the name given to the sheep disease when it suddenly appeared in Iceland in the 1930s. Like the AIDS virus, visna virus induces a complicated disease syndrome. The signs in sheep included lymphadenopathy (infected lymph nodes), encephalitis (brain inflammation), wasting, and susceptibility to infections, the most common of which was an acute pneumonia caused by a bacterium that probably resided in Icelandic sheep populations before visna virus came along.

Lentiviruses that have since been identified in other animals induce a variety of disease syndromes. Caprine (goat) arthritis encephalitis virus, which is genetically very closely related to visna, causes crippling arthritis, paralysis, and encephalitis in goats. Horses are vulnerable to a lentiviral agent called equine infectious anemia virus, which causes intermittent anemia, bouts of fever, and immune-complex glomerulonephritis, an inflammatory disease of the kidneys occurring secondary to the infection. The lentivirus of cows, bovine visnalike virus, also affects the lymph system and causes persistent lymphocytosis, an excessive production of white blood cells.

When observed under an electron microscope, all of the lentiviruses, including the AIDS virus, share a common physical structure. Each infects cells of the immune system, although the specific target cell and the level of interference with the host's immune response differ from species to species. Visna and caprine arthritis encephalitis viruses seem to attack the large white blood cells, the monocytes and macrophages. These cells normally devour foreign bacteria and cellular debris and are a first line of defense against infection. Besides attacking the T-cells, HTLV-III also infects monocytes and macrophages, as well as antibody-producing lymphocytes. Whether other cells of goats and sheep are affected by lentiviruses is not known, since their immune systems have not been as intensively studied as that of humans.

Further analysis of the relationship between the AIDS virus and visna virus awaited direct comparison of their genetic



General retrovirus structure
Joe LeMonnier

sequences. For if it could be proved that the AIDS virus is genetically related to the lentiviruses, some of the disease's mysterious processes would begin to make sense. DNA hybridization using cloned DNAs of the viruses, an effective way of grossly estimating genetic relatedness, revealed that the AIDS virus and the lentivirus resemble one another even on the very basic level of their DNA sequences. Of the several genetic likenesses investigators saw, the most dramatic was the similarity in the gene for coding reverse transcriptase. This gene, in fact, has changed the least in the evolution of retroviruses, and virologists now depend upon it to determine phylogenetic information for the group. Overall, the AIDS virus and visna virus had significantly more DNA sequences in common than either did with any oncovirus tested, including HTLV-I and HTLV-II.

By this time it was evident that HTLV-III and visna virus were close cousins. But the question of whether HTLV-III was also related to other lentiviruses awaited testing of other representative species. Equine infectious anemia and caprine arthritis encephalitis virus were subsequently cloned and showed an equal amount of likeness with HTLV-III. Clearly, the AIDS virus was a lentivirus.

Final confirmation came from DNA sequencing, which allows nucleotide-by-nucleotide comparisons of the reverse transcriptase gene and the rest of the virus genome. (Each nucleotide represents a single letter of the genetic code.) It demonstrated that the genomes for HTLV-III and lentiviruses were similar in organization and coded for similar sets of genes in the same order and location. This information was important, because sequencing determines how the virus is assembled, how it works, and what it looks like.

In 1985, not long after the structural and genetic studies were reported, another important clinical manifestation of AIDS was recognized. Physicians began to realize that neurological signs and symptoms that they had been seeing in AIDS patients—chronic meningitis, dementia, encephalopathy, loss of motor coordination, and paralysis—were caused directly by the AIDS-virus infection. The findings suggested that HTLV-III was attracted to brain cells as well as to white blood cells. In retrospect, in view of the virus's demonstrated close association with the visna and caprine retroviruses—both of which cause neurological disease—the findings should not have been that surprising.

A great deal was being discovered about HTLV-III, but much of it boded ill for the development of a vaccine. On the one hand, since the virus was exogenous (transmitted from outside), there was an inherent "weakness" in its replicative cycle that could be exploited. Uninfected persons could theoretically be protected via vaccination, as has been done with other horizontally transmitted viral diseases, such as measles, mumps, and smallpox. But the AIDS virus is a retrovirus, and to date an effective vaccine has been made for only one retrovirus, feline leukemia virus, a cancer-causing retrovirus of cats. Although this vaccine has not totally contained the disease—probably because some apparently healthy cats had already been infected—its existence at least raises the possibility that a successful human retrovirus vaccine can also be developed.

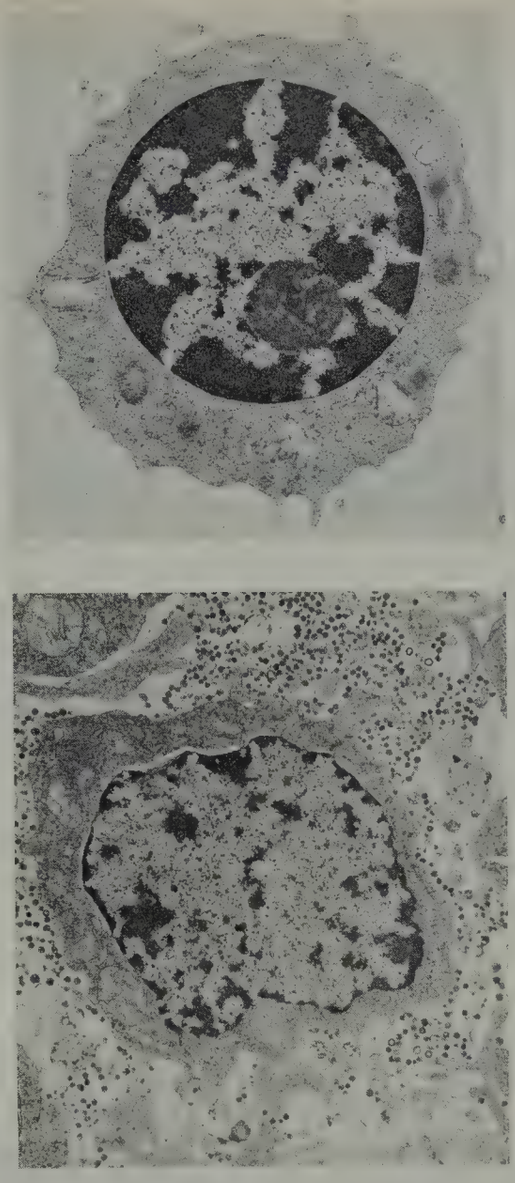
Normally, the host immune system counters infection by making protective antibodies that are specially adapted to adhere to and destroy a specific attacking virus. Lentiviruses, however, have developed novel strategies to avoid elimination by the host. Visna virus and equine infectious anemia virus, for example, undergo rapid changes in the gene responsible for their characteristic protein coat. This capacity for rapid change, called antigenic drift, produces variants of the virus that are not recognized by the host's protective antibodies, which were effective in neutralizing the original strain. The variant viruses thus escape destruction and can continue to infect and, sooner or later, to induce a new cycle of disease. (An analogous process takes place in the envelope of the influenza virus and has created a major stumbling block in obtaining a single effective flu vaccine.)

Caprine arthritis encephalitis virus has another means of evading destruction. It evokes a very weak immune response; the antibodies that do respond seem to do so only halfheartedly and do not kill the virus. The AIDS virus seems to act similarly in this respect, and even though antibodies are present, they do not appear to prevent severe disease or predict survival for the patient. Additionally, the envelope gene of HTLV-III is quite variable, indicating that both of the mechanisms described may be at work.

Effective vaccines have not been made for any lentiviruses, so that producing an AIDS vaccine is no trivial task. Any knowledge gained about lentivirus disease in animals will contribute to the effective control of AIDS.

HTLV-III was presumably introduced into the United States in the 1970s, and AIDS was first recognized clinically in 1981. Although no one knows whether the HTLV-III-induced syndrome is a new disease or where it came from, serologic data are now accumulating to suggest that the virus was in Africa at least a decade before it came to the United States, probably via Haiti. What we don't know is whether the virus was present in humans before the first documented evidence or whether it came from an animal reservoir. We can only speculate on these possibilities. If the virus was widely present in humans before that time, it must have gone through a genetic change that made it more pathogenic. But there are no data at present to substantiate the coexistence of pathogenic and nonpathogenic forms of the virus. It is hard to believe that the nonpathogenic version could have died out in the few years since giving rise to a pathogenic form.

Another possibility is that there exists a lentivirus family group in animals that resembles the AIDS virus even more closely than already identified lentiviruses and that a virus in this group gave rise to a human variant. A newly isolated virus, called STLV-III (simian T-lymphotropic



Top: A normal T-4 lymphocyte. Bottom: A T-4 lymphocyte that has been attacked by the AIDS virus.
Kunio Nagashima and Matthew Gonda

'irus type III), causes an AIDS-like syn-lrome in the macaque monkey. The sim-an virus resembles the AIDS virus in growth characteristics and structure, and t is attracted to similar cells. These data uggest that STLV-III may also be a entivirus. Moreover, the presence of trongly cross-reactive antibodies to STLV-III in the blood of apparently ıealthy wild African green monkeys sug-gests that the virus is not disease produc-ng in one species and quite pathogenic when it is transmitted to another—in this case, the macaque.

How close is the relationship between the simian virus and the AIDS virus? There is at least the possibility of a mon-key retrovirus giving rise to a human vari-ant. Human leukemia virus type I, for instance, has a correlate in a simian virus (simian leukemia virus type I), to which it is remarkably similar in terms of DNA. There have been no direct comparisons of the AIDS-virus DNA and its simian coun-terpart, but serological analyses have pro-vided some evidence that the AIDS virus may be closer to STLV-III than it is to other lentiviruses. However, the two are not nearly so closely related as the human leukemia virus type I and the simian leu-kemia virus type I. Even if STLV-III crossed from monkeys to humans, it is unlikely to have diverged so much in such a short time, to become HTLV-III.

A better analogy may be found in the sudden appearance of visna virus in sheep, first described by Bjorn Sigurdsson, a physician. Before 1933, visna was un-known in Iceland. That year, the govern-ment purchased twenty karakul sheep from a farm near Halle, Germany, where a visnalike virus was endemic. (The dis-ease in Germany was less severe than what was later seen in Iceland.) When the sheep arrived in Iceland, they were put into quarantine for several weeks and then distributed to farms scattered all over the country. At least two of the introduced breed apparently carried the infection at the time of quarantine because by 1935, there were outbreaks in two widely sepa-rated districts. Until 1939, however, no one realized that the disease was an en-tirely new entity. The losses were enor-mous. Between 1939 and 1952 at least 150,000 animals died of the infection.

Between 1949 and 1951 all the sheep in the southern part of the island were de-stroyed in an attempt to control the virus, and ultimately the disease was brought under control. It is now known that visna can be easily transmitted from ewe to kid during feeding, especially through the vi-rus-laden immune cells found in the colos-trum, the fluid secreted by the mammary glands before milk appears. Chance abra-sions of the skin or mucous membranes are other possible modes of entry, as are the bites of blood-sucking insects, which are implicated in the spread of equine infectious anemia. It could also be that centuries of isolation made Icelandic sheep particularly susceptible to visna.

If HTLV-III is not a new virus, has not recently jumped into the human species from an animal reservoir, and is not a mutation of a known nonpathogenic virus, what plausible explanation can account for its sudden appearance in humans? Drawing on the parallels with visna, we can make some educated guesses. It is possible that the virus has existed in humans in central Africa for hundreds of thousands of years, but that it resided in an isolated population. Such isolated groups may have coadapted with the vi-rus, lessening the severity of the infection and allowing for mutual coexistence. The persistence of HTLV-III in this scenario may lie in old customs such as scarifica-tion and the sharing of needles used for body marking. Parallels exist in the spread of kuru, a slow-acting and fatal viral dis-ease of the nervous system. Kuru is found only in a specific tribe in New Guinea and is spread exclusively by rites associated with cannibalism.

Demographic factors, too, may have a bearing on the spread of AIDS. In the past thirty years, Africa's tribal and geographi-cal boundaries have broken down as indi-viduals moved toward cities for a variety of reasons. Such changes could have brought an infectious agent into contact with previously unexposed populations, both international and local, and the dev-astating effects of the virus would have been felt more readily, as when visna virus was introduced to Iceland.

Such a pattern of sudden virulence has often been seen when other pathogens have reached unexposed peoples. Exam-ples include the fatal measles epidemic in the Faroe Islands (1781) and the Fiji Is-lands (1875), and the devastating effects of smallpox on American Indian popula-tions after contact with Europeans in the sixteenth century. Anthropological stud-ies in central Africa may provide further insights into such a scenario.

Fortunately, the AIDS virus, unlike smallpox or measles, is not easily transmit-ted, and unlike some other retroviruses, it cannot be transmitted from generation to generation. Therefore, even in the absence of a vaccine, we can expect that preven-tive measures already in place can effec-tively prevent the spread of the disease.

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Three Planets Strut Their Stuff

by Thomas D. Nicholson

Jupiter, Mars, and Saturn are a spectacular sight in the morning sky this month, stretched along the zodiac from east to west. Jupiter now rises an hour or so after midnight, so it is well up in the east at dawn, a beacon in the growing light. Mars is already up at midnight, and it brightens dramatically during the month. In the morning it is high in the south, easily identified by its brightness and reddish color. Its prominence will help you find Sagittarius easily. Saturn is up from dusk until dawn and is now at its peak brightness. Find it in the west at daybreak, but be careful not to confuse it with Antares, the reddish star nearby in Scorpius.

Remember that the planets do not stray far from the earth's orbital plane as they move around the sun. Jupiter, Mars, and Saturn are like beacons along that path in May's morning sky. Note also that a number of bright stars—Antares, Spica, and Regulus—lie virtually along the line of the planets. You will also find the moon close to the same line. From about the 20th to the end of the month, watch it as it moves past those stars and planets.

The three bright morning planets are gradually working into the evening sky. Saturn is already visible from dusk until dawn, and Mars is rising noticeably earlier from night to night. In a month or so, these same bright planets will dazzle us in the evening. With brilliant Venus already there, the summer sky this year will be special indeed.

Events in the calendar below are given in local time unless otherwise indicated.

May 1: After yesterday's last-quarter phase, moonrise occurred this morning about two o'clock, and moonset about an hour before noon. Tonight the moon rises even later as it works its way east toward the sun.

May 3: Jupiter and the waning moon rise together this morning, as the moon passes just to the south of the planet on its way out of the morning sky.

May 5–6: We can surely see the waning crescent moon rising in the east before dawn on the 5th and possibly on the 6th as well, but not thereafter.

May 8: New moon is at 5:10 P.M., EST, in Aries.

May 10: We should see the young crescent moon tonight, two days past new. Look in the west after sundown. It is at apogee, farthest from the earth.

May 11: The moon catches up to Venus, passing above it this morning. They should be visible close together in the west tonight. Now is the time to get familiar with that bright planet. It will become increasingly conspicuous this spring and summer.

May 13: Pollux and Castor, the shining twin stars of Gemini, join the crescent moon in the west tonight as darkness deepens.

May 15: The crescent is midway between Pollux and Castor (below) and Regulus (above) early this evening.

May 16: First-quarter moon, at 8:00 P.M., EST, is very close to Regulus tonight, with the large figure of Leo, spring's celestial lion, towering above.

May 18–21: The moon spends these four nights in Virgo, widening after first-quarter phase. On the 18th, it is just moving over the border from Leo into Virgo. On the 21st, after passing bright Spica during the day, it moves into Libra.

May 22: After completing its stint as a morning star, Mercury swings over into the evening, passing the sun from right to left in going through superior conjunction, beyond the sun in our sky.

May 23–24: Full moon is at 3:45 P.M., EST, in Scorpius. About six hours later, the moon is at perigee, nearest the earth. The perigee effect should substantially increase the strength of the spring tides on the 24th. Despite the brightness of the full moon, Saturn and Antares should be clearly visible near the moon. The moon passes below Saturn at midnight, EST, on the 23d, and then passes Antares at about 3:00 A.M., EST, on the 24th. The moon covers Antares as it goes past the star (an occultation) over central and western North America.

May 25: The waning moon moves across Sagittarius tonight right through the top of the "teapot."

May 26: Mars and the moon rise together after 11:00 P.M., in Sagittarius.

May 27: Saturn becomes an evening star when it is at opposition from the sun. Even though it can still be seen in the dawn sky (because at opposition it is in the sky all night long), it now begins to rise before sunset and set before sunrise.

May 30: Last-quarter moon, in Aquarius, is at 7:55 A.M., EST. The moon is now a morning object, rising after midnight.

May 31: Jupiter is near the moon in the dawn sky, near the border of Aquarius with Pisces. Moon and planet rise after 1:00 A.M. and remain above the horizon after sunrise. You should be able to see the crescent, to the sun's right, during the day until it sets after noon.

Editor's note: The Sky Map in the April issue shows the evening constellations and stars for this month and gives the dates and times for use.

Bye-bye Halley!

Comet Halley is slipping away. It sinks below the limit of naked-eye seeing (usually placed at a magnitude of plus 6 in perfect viewing conditions) on May 1 after four and one-half months (since December 10) of being brighter. It reached a

timated magnitude of plus 3 in early ebruary, about fifteen times brighter ian on May 1. Unfortunately, as we iow, it was behind the sun during its rightest days and therefore was not vis-ile from the earth at that time. The omet will not again be bright enough to e without optical aid for more than sev-nty-five years.

Eager comet watchers should still be ble to see Halley in early May, however. will be an easy binocular object, as good s or better than when we saw it on much ss comfortable nights last December. vening skies should be dark enough; full ioon was on April 24, and moonrise isn't ntil about 2:00 A.M. on the 1st. Our map nis month will help locate Comet Halley mong the easily recognized stars of the pring.

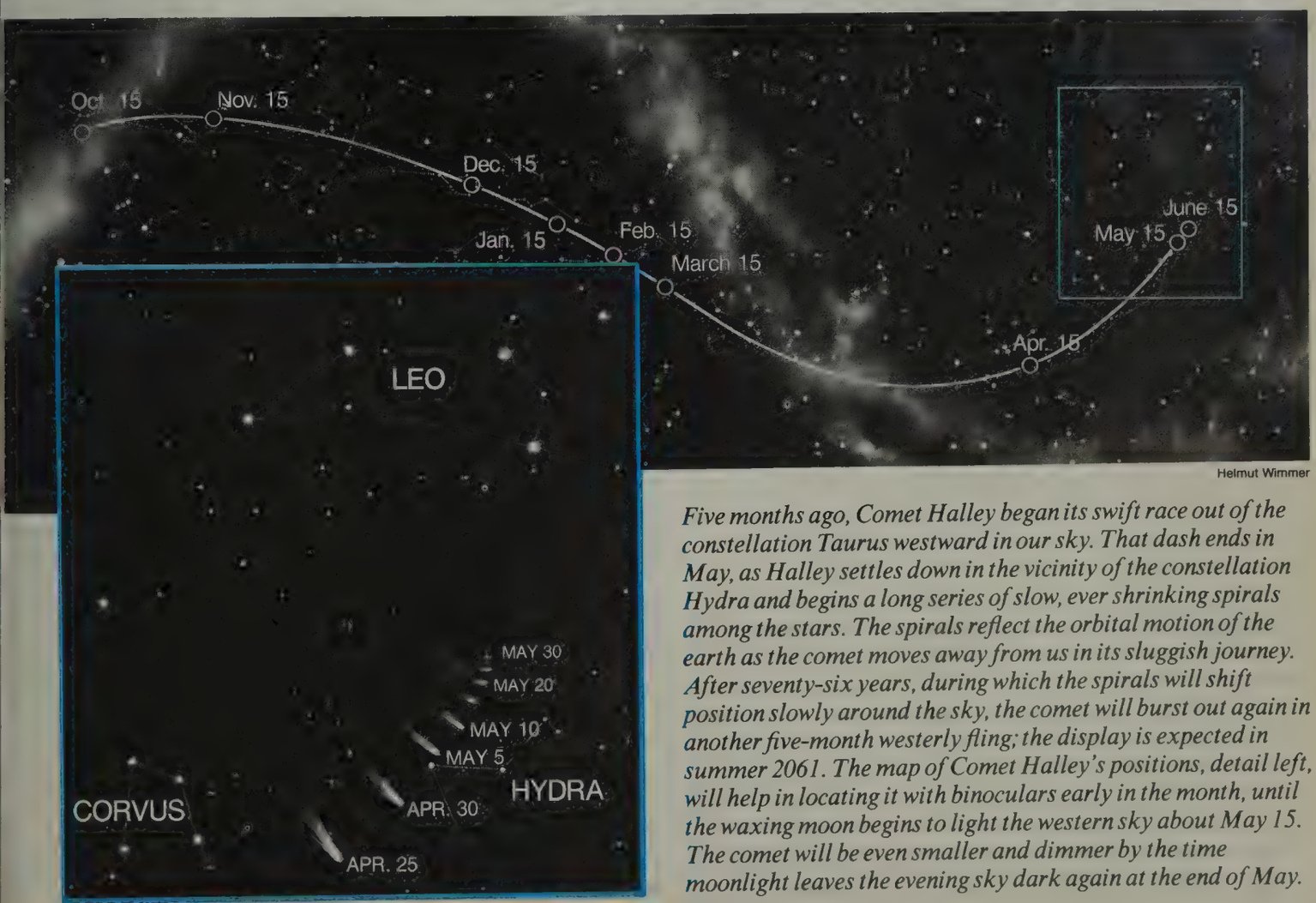
Comet hunting should be good, weather ermitting, until about the 15th, when the waxing moon will again brighten the eve-ing. By the time the waning moon leaves he evening sky (about the 27th), the omet will have faded by about 3 magni-udes and will be only one-fifteenth as right as on the first of the month.

The reason for the rapid dimming of Comet Halley during May is apparent when viewing its position in the solar sys-em. Well beyond the orbit of Mars, it is noving in a direction virtually opposite to the earth's motion, so that the two separate at close to their combined speeds, about 126,000 miles per hour. At this relative velocity, the distance between Comet Halley and the earth more than doubles during the month of May, from about 74 million miles on May 1 to nearly 165 million miles on May 31.

But this is only the beginning of Halley's long journey out from the inner solar system. When it whipped by the sun at its closest point, 54 million miles on February 9, the sun's gravity had accelerated it to a maximum speed of nearly 122,000 miles an hour. The momentum it gained will sustain its outward journey for almost thirty-eight years before it slows down enough to turn inward toward the sun once more. Then, out beyond the orbit of Neptune, over 3.2 billion miles from the sun and slowed to a speed of only 2,000 miles per hour, it will begin to fall toward the sun again. After thirty-seven or so more years, another generation will have its turn with this most famous of comets in the year A.D. 2061.

Cometary appearances in the past have often been associated with disaster, misfortune, or a change in human affairs. Comet Halley's history is studded with examples. Rome was at war with Carthage during its first recorded appearance (240 B.C.), and with Jewish revolutionaries centuries later during another appearance (A.D. 66). Attila the Hun met his defeat in France when Halley visited in A.D. 451, and the Moors were battling Jewish and Christian rebels in Toledo, Spain, during another visit. The comet appeared for the Norman conquerors of England in 1066, and for Pizarro and his conquistadors as they left on a voyage of conquest to Peru in 1531. English colonists were settling Jamestown when Halley returned in 1607, and they were waging the French and Indian War during its 1759 visit. The 1910 appearance has often been associated with events that led to the great world wars of the twentieth century. And we have yet to see what future historians will do with its 1986 appearance.

We cannot help but wonder, as Halley leaves our sky to begin another of its long cycles, what kind of world it will find when it returns in three-quarters of a century. No serious person puts much credence in the old belief in comets as "evil stars." Yet no one can deny Halley's link with so many great events in human history. It is as though the comet were a mirror, reminding us of what humanity was like and was doing each time it returned. If the history it mirrors in its thirty visits is all too often disturbing, that is the way human affairs usually were! The power to change the history is in us, not in the comet. □



Helmut Wimmer

Five months ago, Comet Halley began its swift race out of the constellation Taurus westward in our sky. That dash ends in May, as Halley settles down in the vicinity of the constellation Hydra and begins a long series of slow, ever shrinking spirals among the stars. The spirals reflect the orbital motion of the earth as the comet moves away from us in its sluggish journey. After seventy-six years, during which the spirals will shift position slowly around the sky, the comet will burst out again in another five-month westerly fling; the display is expected in summer 2061. The map of Comet Halley's positions, detail left, will help in locating it with binoculars early in the month, until the waxing moon begins to light the western sky about May 15. The comet will be even smaller and dimmer by the time moonlight leaves the evening sky dark again at the end of May.

Words and Chimps

by Colin Beer

"How can I know what I think till I see what I say?" In these words, as reported by E.M. Forster, an old lady once pithily represented a view held currently by a number of philosophers and psychologists: that language is prior to thought, and the medium of its realization. This view has obvious bearing on ideas about the mental lives of animals for it implies that if animals lack language, they must be unthinking things, and also that if they think at all, they must do so by some linguistic means.

The idea that access to an animal's mind might be through its use of, or capability with, something like language presents two possibilities for exploration. One is for the scientist to decipher the code of the animal's communication system and so get the animal to express its thoughts in its own words, so to speak. This is the "King Solomon's Ring" approach favored by Donald Griffin, whose book *Animal Thinking* I previously reviewed (*Natural History,* June 1984). The other approach is to try to teach the animal something like human language and so get it to reveal its reasoning capabilities in words, just as we do. Efforts employing this approach are the subject of David Premack's book *Gavagai! or the Future History of the Animal Language Controversy.*

The book assumes that the reader is acquainted with the animal language projects involved in the controversy of its title. The best known of these projects are those concerned with apes. There is also work with dolphins and a parrot. Several different schemes have been tried, including American Sign Language, a system of symbols (lexigrams) communicated via computer keyboard and display screen, and Premack's own system of colored plastic shapes that can be attached to a magnetic board. In a manner comparable to those of the other projects, Premack has trained his chimpanzees to treat the plastic shapes as labels for objects, properties, actions, and relations, and to construe and compose combinations and permutations of the pieces of plastic on the board as statements, requests, and questions.

GAVAGAI! OR THE FUTURE HISTORY OF THE ANIMAL LANGUAGE CONTROVERSY, by David Premack, *The MIT Press, $12.50; 164 pp.*

I think there is general agreement that the animals trained in these projects have mastered much more than was once thought possible. Nevertheless, opinion is deeply divided about just what has been mastered and what it implies about the mental lives of the animals concerned. Some claim that the animals acquired the essentials of human language and, in so doing, revealed capacities continuous with human cognition. Others interpret the results of the training as continuous with the kinds of associative learning achieved by rats in mazes and pigeons in Skinner boxes, which is different in kind from what is involved in true language acquisition.

At the start of his book, Premack represents the animal language controversy as a confrontation between emotionally entrenched positions. One side holds to a conviction—derived from a conception of Darwinian evolution—that to the extent that human beings differ from animals, it is always in degree, never in kind; the other side is equally set in the belief that human beings are unique, at least in psychological respects. Premack might also have noted that the division falls roughly where William James drew one between "tender minds" and "tough minds," that is, inflationary inclination to make the most of what evidence might suggest, contrasted with deflationary scepticism discounting anything beyond the least that evidence cannot rule out. Premack finds neither psychology nor biology nor linguistics to be sufficiently disinterested to provide terms for mediation. According to him, the trained apes appear more than mindless, yet less than linguistic; but he takes the position that preoccupation with language distracts attention from deeper dimensions for cognitive comparison.

Examination of some of the research on which the animal language controversy is based leads Premack to conclude that linguistic claims have frequently been made for performances that do not warrant them. From his own work with chimpanzees, Premack has evidence of representational and conceptual capacities, including acquisition of rules, that were revealed by the linguistic training but appear not to have been derived from or dependent on it. In general, he finds the performances resulting from the animal language research to be products of learning and revealing of learning capacities. But the prevailing view of human language acquisition, to which Premack accedes, holds there is more to the process than learning.

Children apparently start out, much as chimps do, by picking up word/meaning associations piecemeal; but they then reorganize what they have learned by extracting regularities from it, and thus derive syntactic rules for generating plurals, changes of tense, and so forth. This reorganization phase is marked by errors where there had previously been superficial flu-

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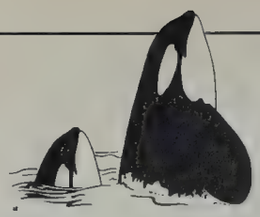

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ency ("foots" in place of "feet" and "runned" instead of "ran"). This phase is believed to be due to "hard-wired" processes, rather than learning, for according to the current view, no amount of ordinary associative learning would be sufficient to establish the syntactic competence that emerges. Whatever the nature of the supposed built-in, rule-extracting routines, which presumably also partake in the aforementioned "language of thought," there is no evidence of them in animals. Consequently, the trainer attempting to impart language to animals must "simulate by a process of learning that which we ourselves cannot carry out by learning." This is no "recipe for language" in Premack's view: "It will not produce grammatical classes, hierarchical organization, recursion; nor mental representation by and through the would-be language system; nor any of the other properties basic to human language."

Nevertheless, Premack has plied his chimpanzees with language lessons as persistently and ingeniously as anyone. The disparity between what he seemed to be pursuing and the position at which he has arrived is offset by the extent to which his approach has gained new access to the mentality of apes. He uses much of his central and longest chapter, "What Is a Word?" to describe and discuss the results of his experiments. In the course of this, he unriddles the odd title of his book.

"Gavagai" is an utterance invented by the philosopher Willard Van Orman Quine, who used it in his book *Word and Object* to develop an argument about the "indeterminacy of radical translation." Quine's scenario had an English-speaking linguist in a strange land encounter a native who says "gavagai" in circumstances suggesting that the utterance means "rabbit." Quine argued that because the linguist shared no words with the native, and therefore had only the circumstances of the utterance and responses to pointing to go on, he could, at best, have determined only the "stimulus meaning" of the term, leaving many possibilities open for what the native meant by it. This calls into question Lemuel Gulliver's account of how swiftly he got on talking terms with the strange creatures he met in comparable situations. Premack, however, maintains that there are behavioral, even nonlinguistic methods for pressing the quest for meaning beyond where Quine left it. By using such methods to test his chimps, he has been able to elucidate what plastic "words" can and do mean to them and so contemplate such questions as their grasp of causality and whether they can appreciate the asymmetry of class inclusion (for example, "rabbits are mammals" does not mean that "mammals are rabbits").

In his next chapter Premack examines whether the linguistic levels attained by his trained chimps include two features closely related to human language: discrimination of temporal order (judgment of whether red, yellow, and green, successively flashed, match the order of a comparison sequence of the same colors) and emotional association ("the power of speech/To stir men's blood"). He does this to probe whether differences between ape and human linguistic performance might be due to the ape's lack of one or more of the "competencies" contributing to the human case. The test for temporal discrimination proved positive, and there was evidence that emotion can be connected with chimp communication, at least in a crude form. As far as it goes, then, this evidence is consistent with the view that something more pervasive than a missing ancillary component would be needed to bridge the gap between animal and human linguistic capacities.

Premack's final chapter resumes discussion of the nature of this discontinuity.

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t develops further the contrast between he human "syntactic engine" and the lim-ted semantic categories to which the ape s restricted. That the ape system is not loser to the human system puzzles Premack less than why the human system s so far in advance. The ape's system is apable of performing what can be re-garded as the two principal functions of anguage—a means of referring to ob-ects, states, and so forth, and a means of ignifying whether statements concerning uch references are true. In contrast, the grammatical apparatus of human lan-guage provides for complexities and sub-leties of signification bereft of any clear basis in biological adaptive significance; and Premack defies anyone to dream up a scenario to account for human linguistic capacity in terms of evolutionary fitness. He suggests an indirect approach to the problem: to lift our gaze from its con-centration on language itself to take in the whole complex of peculiarly human so-cial, mental, and moral dispositions served by it, especially pedagogy, aesthetics, so-cial attribution, and consciousness. This reminds me of a view expressed by Lud-wig Wittgenstein, who argued that full comprehension of language requires appreciation of the "way of life" in which it is embedded, and hence that "if a lion could talk, we could not understand him." I also wonder whether Premack's sugges-tion might bear on that equally isolated and comparably remarkable sign system, the dance "language" of bees.

Premack's essay is unusual for the ease with which it moves among the disciplines of philosophy, psychology, biology, and linguistics. Such versatility is nevertheless commensurate with the demands of the subject. It in turn places demands on the reader. The book assumes some familiar-ity with the relevant literature and the concepts and terminology of the animal language field. Some leaps and twists in the train of thought offer tests of mental agility. But the way is smoothed by clear writing and enlivened by touches of hu-mor. *Gavagai!* will make a stir among experts in the field and is likely to make a lasting contribution to the future history of the animal language controversy. In the meantime, part of its message might be paraphrased in a question: How shall we know what animals can say till we see what they think?

Colin Beer is a professor of psychology at the Institute of Animal Behavior at Rutgers University. A New Zealander, Beer earned his doctoral degree under the direction of Niko Tinbergen at Oxford University.

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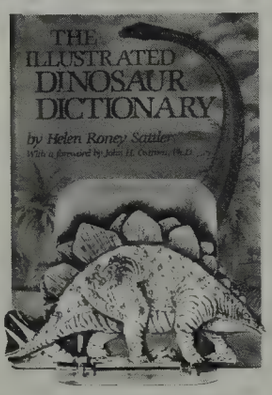

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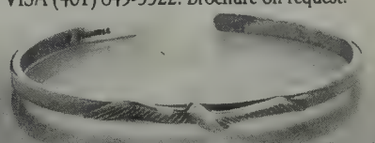

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Pink Cliffs, Utah

by Robert H. Mohlenbrock

The rough mountain terrain in the southwestern corner of Utah, a few miles east of Cedar City and Saint George, is called the Land of Color. Visitors flock to the region's national parks, such as Zion, to see the brilliant exposures of the Wasatch Formation, a mass of limestone deposited during Eocene times, some 40 million years ago. The park lands surround the lesser-known Dixie National Forest, whose precipitous Pink Cliffs, tinted by small quantities of iron and manganese oxides, are among the most spectacular parts of the formation.

I got my first glimpse of the Pink Cliffs one summer morning, as I made my way on back roads northeast of Zion National Park. Following a sign that pointed down a gravel road to Cascade Falls, I soon came to a scenic overlook. Below me, at an elevation of 8,000 feet, flowed the North Fork Virgin River, whose erosive action had shaped the cliffs. Perforated by honeycomb depressions lined with calcite crystals, the iridescent cliffs towered 1,700 feet. From the overlook, a narrow trail led to the Cascade Falls, which emerge midway down the cliffs and tumble into the river below.

Plant life is sparse on the exposed cliffs because of the scarcity of water, the absence of all but a few soil microorganisms, extremely poor aeration, and extensive fluctuation of soil temperatures. The most picturesque plants are the bristlecone pines. The California counterparts of these ancient, gnarled trees were featured in this column last May. The shrubby mountain mahogany, whose feathery fruits are conspicuous in autumn, is a frequent associate of the bristlecone. Although the rocky soil is often bare of vegetation, occasional flashes of color are provided by the dwarf blue columbine and the daisylike goldenweed.

Robert J. Warren

The sun sets over Navajo Lake.

The Pink Cliffs form the south wall of the Markagunt Plateau, a 25-mile-wide block that was uplifted 12 million years ago through violent shifting of the earth. The western edge of the block was elevated nearly 3,000 feet higher than the eastern edge, so the plateau tilts sharply. After the uplift, perhaps as recently as 1,000 years ago, volcanic eruptions covered much of the plateau with lava. Scanning the horizon from the Cascade Falls overlook, one can see a few scattered cinder cones. Lava flows define much of the topography, but where the soft, sedimentary rocks of the Wasatch Formation are exposed, streams have modeled the surface into a series of long ridges and broad, flat-floored valleys.

Navajo Lake, 714 acres of clear blue water, is the focal point of the plateau. It owes its existence to volcanic eruptions that dammed up broad Duck Creek Valley. The lake is a geological phenomenon, for it has no surface outlet nor is it filled from streams on the surface of the plateau. Instead, rainfall, snowmelt, and several small perennial springs supply its water. Navajo Sinks, a series of sinkholes formed at the eastern end of the lake by hundreds of years of the water's dissolving action on the limestone, provides the lake's only outlet.

Through a series of experiments, in which they added fluorescent dye to the lake, geologists M.T. Wilson and H.E. Thomas were able to show that water

Robert H. Mohlenbrock

Joe LeMonnier

Pink Cliffs
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flowed from Navajo Lake through the series of sinkholes and into an interconnected underground reservoir and system of channels. About two-fifths of the excess water from Navajo Lake meanders through these underground channels until it bursts through an opening in the Pink Cliffs as Cascade Falls. The remainder appears about three miles to the east at Duck Creek Springs. From these springs, the water flows two and one-half miles along Duck Creek and Duck Lake before disappearing into Duck Creek Sinks, eventually emptying into the Sevier River to the east.

The features of the Markagunt Plateau illustrate the concept of biological life zones, developed in 1894 by Clinton Hart Merriam. An American biologist who had served as naturalist on the Hayden surveys in Utah, Idaho, Montana, and Wyoming, Merriam divided the biological communities of North America into east–west belts. He distinguished the different belts by their plant and animal composition, which, he proclaimed, was controlled by temperature. Thus Merriam's Boreal Life Zone is found in the far north, while the Sonoran Zone occupies the semiarid southwest. Merriam also maintained that in mountainous regions, such as southwestern Utah, zones similar to these can be found at differing elevations—the summits of the highest mountains are Boreal, their bases are Sonoran. A very general rule of thumb is that every increment of 1,000 feet above sea level is equivalent to 600 miles in a south–north direction. By ascending a mountain one encounters life zones in the same sequence that one observes driving hundreds of miles from south to north.

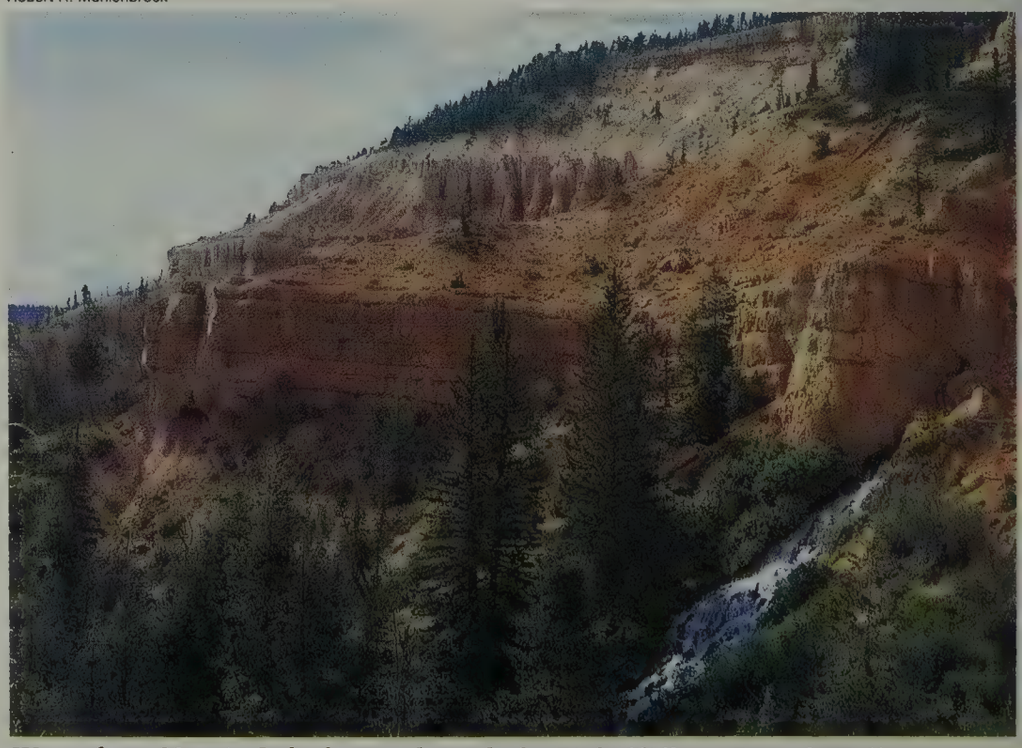
Between approximately 7,500 and 8,500 feet on the Markagunt Plateau is the Transition Life Zone. Ponderosa pine is the dominant species, usually occupying gentle slopes. These trees allow enough sunlight to reach the forest floor to encourage growth of manzanita, bitterbrush, and mountain ceanothus. Hayle Buchanan, a botanist at Weber State University in Ogden, Utah, who has spent more than two decades studying the plants in Utah's Land of Color, has noted that occasional depressions in the Transition Life Zone are home to a community dominated by sagebrush and a wide diversity of grasses and wildflowers. Buchanan noted that when young ponderosa pines and Rocky Mountain junipers from nearby forests attempted to invade these treeless areas, they were unable to survive because cold air drainage from higher mountains caused severe minimum winter temperatures. Daily temperature fluctuations were a further obstacle to woody plant growth.

The Canadian Life Zone occupies forested slopes from 8,500 to 9,500 feet. Ponderosa pine and Rocky Mountain juniper grow where the slopes are more exposed and therefore drier, but on moist slopes, white fir and Douglas fir are the dominant species. Because of the intense shade, few wildflowers are able to grow beneath these trees. Above 9,500 feet, along the high road between Navajo Lake and Duck Creek Springs, treeless meadows have developed over old lava flows. These meadows, which are assigned to the Hudsonian Life Zone, are covered by snow for as much as eight months of the year, so that the wildflowers and grasses that live there must complete their life cycle in a very short time. Penstemons, paintbrushes, orange sneezeweeds, long-plumed avens, goldenrods, and asters are vivid from late June to mid-August.

While Merriam's life-zone concept was widely accepted at one time, it has fallen into disfavor, partly because the various zones cannot be recognized across the continent on the basis of uniform plant and animal communities. Nevertheless, biologists continue to use Merriam's life-zone designations in those areas where they seem to apply.

"This Land" highlights the biological phenomena of the 153 U.S. national forests. Robert H. Mohlenbrock is distinguished professor of botany at Southern Illinois University at Carbondale.

Robert H. Mohlenbrock



Water from Navajo Lake bursts through the Pink Cliffs at Cascade Falls.

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Shoestring Tales

Conquering John, Dee Dee the Devil's Daughter, and other folk characters will come to life in the Kaufmann Theater when the *Shoestring Players* act out tales from around the world. This family program will take place on Sunday, May 4, at 11:00 A.M. and 1:30 P.M. Tickets, which must be ordered in advance, are $2.50 for members and $5.00 for nonmembers. For information call (212) 873-1327.

Harlem Is Heaven

In the late 1930s and 1940s Harlem's Apollo Theater and the Cotton Club were part of a national musical renaissance. Big bands like those of Count Basie and Duke Ellington performed for people from all walks of life, and blues singers like Billie Holiday and Ella Fitzgerald received raves across the nation as well as overseas. On Saturday, May 3, at 2:00 and 4:00 P.M. in the Kaufmann Theater, the Black Patti Foundation, in conjunction with the Museum's Department of Education, will present a program about this musical era, including vintage slides and film clips. Dancers Marion Cole and Harriet Brown will be special guests. Free tickets for both performances will be distributed at the Kaufmann Theater ticket booth beginning at noon on the day of the performance. For additional information call (212) 873-1300, ext. 514.

Forest of Bliss

Robert Gardner, one of the world's leading ethnographic filmmakers, presents new work shot in Benares, India, a famed religious center on the river Ganges. The filmmaker will be present at the screening to answer questions from the audience. *Forest of Bliss* will be screened on Wednesday, May 7, at 7:00 P.M. in the Main Auditorium. Tickets are $6.00 for members and $7.00 for nonmembers and must be ordered in advance. For information call (212) 873-1300, ext. 559.

Darwin's Ark

When poet Phillip Appleman read Darwin's *Origin of Species,* it changed both his life and his writing. With titles like *Darwin on 14th Street, Black-Footed Ferret Endangered,* and *Mr. Extinction, Meet Ms. Survival,* his poems apply Darwinian ideas to the profound crises facing all living creatures today. On Thursday, May 8, Appleman will read from his most recent volume of poetry, surrounded by the sea otters, fishes, and other animals of the Hall of Ocean Life. The reading is at 7:30 P.M. Tickets are free for members and $4.00 for nonmembers and must be ordered in advance. For additional information call (212) 873-1327.

Versions of the Traditional

Three special programs this month honor the legacy of the Bushmen.

Are the Gods Really Crazy? Friday, May 9, at 7:00 P.M. in the Linder Theater. Marjorie Shostak examines the dignity and balance of !Kung hunter-gatherer life through slides and excerpts of a !Kung woman's life story.

The Stories in the Wind: Tales, Myths, and Legends of the Bushman. Saturday, May 10th, 1:00 P.M. in the Linder Theater. Mellisa Heckler presents a family program of stories celebrating the rich folklore of the Bushmen.

Films of Bushman Life. Saturday, May 10, 3:00 P.M. in the Linder Theater. Among the three films by noted director John Marshall that will be shown today is *Bitter Melons,* a documentary about a small band of Gwi San and their music, dance, and daily life.

These free programs are made possible, in part, by a grant to the Touchstone Center from the New York State Council on the Arts, and seating is on a first-come, first-served basis. For additional information call (212) 873-1300, ext. 559.

Cameos of Ethnic Dance

Dancer, choreographer, and dance educator Matteo returns once again to the Main Auditorium with a troupe of multiethnic performers to present the richness and diversity of dances from around the world. *Cameos of Ethnic Dance* will include short segments of Native American, Indian, Middle Eastern, and American modern dance, among many other styles. Tickets for the program, which will take place on Thursday, May 15, at 7:30 P.M., are $4.00 for members and $7.00 for nonmembers. They must be ordered in advance. For additional information call (212) 873-1327.

Japan Month

May is *Japan Month* at the Leonhardt People Center, which is open from 1:00 to 4:30 P.M. on Saturdays and Sundays. The elegance, subtlety, and richness of Japanese culture will be portrayed in film, dance, crafts, and more. The Center is on the second floor.

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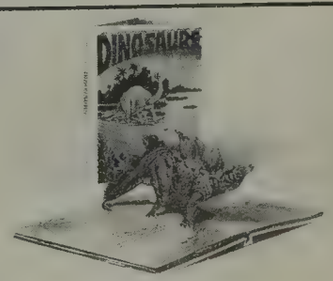

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Chowder Chauvinism

French fishermen crossed the Atlantic long ago and took their favorite fish soup with them

By Raymond Sokolov

Four of France's greatest chefs flew to New York not long ago to cook a benefit dinner for the March of Dimes. But they did not sound or act like soldiers of charity. After gorging at fashionable eateries and taking care of their not inconsiderable American business interests, they looked up from their plates and sneered at American cooking.

Jacques Maximin of Nice's Hotel Negresco was the only one of the four willing to cook with local ingredients, but he was not at all reticent about disparaging young American chefs. "They have no background," he told Marian Burros of the *New York Times,* "no training." Alain Chapel, the three-star pontiff from Mionnay, chimed in: "There is no tradition here." Is Mr. Chapel a student of American food? Of course not. His only previous experience with our multifarious cuisine was at Chez Panisse in Berkeley, California, where the gifted Alice Waters serves a menu overwhelmingly derived from traditional French models. Mr. Chapel found her food "very sincere."

This business about no tradition is just something we Americans have to expect from Europeans. If we want to spend time with them happily, we must give up hope of persuading them that we have been around for a few centuries now as a culture and have thought a few thoughts of our own. Above all, it is no use attempting to tell them that our culture includes their culture.

Old Worlders seem to forget that colonists and immigrants came here as natural-born emissaries of European culture and remained active participants in it. But just try to tell an Italian that Harvard offered a chair to Galileo while his ancestors were persecuting the man. Don't waste your breath informing French intellectuals about the influence of Montesquieu on our Constitution or of T.S. Eliot's debt to French poet Jules Laforgue. Such wild claims will cut no ice with educated Europeans.

Why then should we expect better from Messrs. (note the French borrowing) Chapel and Maximin? They are nothing more than provincial chefs with provincial backgrounds. They know what they know, which is the food of their regions and their country. And they learned that in a way not likely to encourage wide horizons—leaving school at fourteen for toilsome apprenticeships in authoritarian kitchens, spending years at glorified scullery work, chopping mountains of parsley, decorating the stove as if it were a cake to greet the chef in the morning.

No wonder that such men dismiss American chefs with college educations and comparatively brief apprenticeships as parvenus without serious backgrounds in the kitchen. No wonder that such men must insist that "tradition," in their local, inherited sense, matters. And up to a point, they have a point. Many American chefs are six-day wonders, but not all of them. And even the most blatant opportunists in the brave new world of American *nouvelle cuisine* are paying sincere tribute to French tradition. The French chefs might have chosen to greet all this imitation as a sincere form of flattery. Instead, they went for their admirers' throats. And the position they took toward American chefs refutes itself.

They seemed to believe that only chefs born in France and trained as they were can cook at their level. They seemed to be saying that if you and I start out with the same ingredients as they do and follow the same procedures they prescribe in the cookbooks they are only too happy to sell us in English translation, we will fail to produce authentic French food because we have not, in some mystical sense, inherited their traditions.

This is illogical, you might even call gastrofascistic. I don't even think thos chefs meant it. In their hearts, I believ they already know that our mayonnaise as good as their mayonnaise, our lobst medallions in raspberry vinegar no le chic than theirs. But if you were the would you admit that some of your be customers could eat as high on the hog home as in France? Never. Stupidity is n part of their French tradition.

Chauvinism, on the other hand, de nitely is. In fact, it has a little tradition its own, with gastronomic overtones. Th man who gave chauvinism its name, o Nicolas Chauvin, was born at Rochefo in what is now the department of Ch rentes-Maritime on France's Atlanti coast. Had he been a chef instead of soldier, Chauvin would have built a care out of devotion to Charentais regional sp cialties instead of to Napoleon. These sp cialties did and do include mussels cream (*mouclade*), cognac, and a fis stew called *chaudrée.*

Today, *chaudrée* chauvinism ha spread far beyond Rochefort. French fis ermen crossed the Atlantic long ago an took their favorite fish soup with then Then, in the mouths of neighboring En lish speakers, *chaudrée* turned into chow der. (It is also possible that the word chow der descends from *chaudière,* a Frenc term for pot that is also applied to a Breto fish stew.) And in their hands, the form fish stew turned into a milk-based cla soup with bits of rendered salt pork an potato cubes.

This account of the origin of New En land clam chowder leaves out a great dea It does not explain why or when a quit original soup was created. As with mo traditional recipes, no one knows how began. It is not hard to locate recipes f traditional French soups that mix crea and seafood. The Breton *cotriade* calls f

nixture of fish and a modest amount of *ème fraîche* added to the broth. Even oser is the Norman *soupe aux coques*, nich brings together the little bivalve of e Norman shore known in English as ckle (*Cerastoderma edule*) with *crème aîche*. But I have yet to find a really ose analogue to our clam chowder in a ench cookbook. And I doubt I will find ie, because the plainness of our New ngland chowder is its hallmark and its enius.

Somehow, then, the term *chaudrée* (or *haudière*) got anglicized and attached to soup built on the cheapest, most univer- l ingredients along the North Atlantic oast of the New World. Was the birth- ace of chowder in Newfoundland where rench and English colonists mixed? No- ody knows. And the exact moment of spiration that mixed milk and bivalve, ork and potato, is lost in the mists of the arly days of colonial America. But the ish caught on and survived.

By the later eighteenth century, the ord "chowder" had appeared in print. nd by the mid-nineteenth century, it re- eived its literary apotheosis in *Moby ick*. Melville devotes an entire chapter to shmael's chowder supper with Queequeg t the Try Pots in Nantucket. "Oh, sweet riends! hearken to me," he wrote. "It was nade of small juicy clams, scarcely bigger nan hazel nuts, mixed with pounded ship iscuit, and salted pork cut up into little akes; the whole enriched with butter, nd plentifully seasoned with pepper and alt."

This is rich stuff, but you could not use as a recipe. It doesn't mention milk. It oes not give a precise description of the alt pork, which should be chopped and risply rendered (see recipe). Purists will hudder at the presence of cracker crumbs the pounded ship biscuit). And they will lso shake their heads at the idea of tiny

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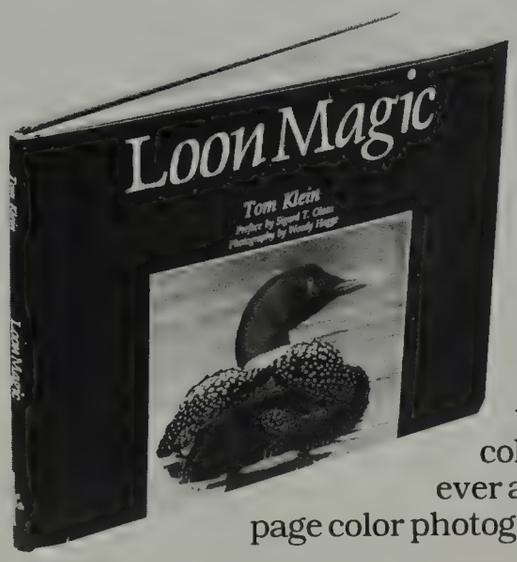

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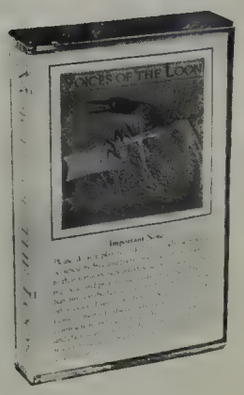

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clams in a chowder. How could Melville not have known that you put big clams in chowder, after chopping them up? For true chowderheads, this last requirement is no quibble. It is the heart of the matter.

I was reminded of this recently, while perusing the latest issue of my favorite food periodical, *Dwarf Conifer Notes*. As I imagine most of you know, *Dwarf Conifer Notes* is published in Little Compton, Rhode Island (P.O. Box 458, Zip Code 02837), every so often by a man who styles himself Theophrastus. He is interested in two subjects, dwarf conifers and the gastronomic specialties of Little Compton: sweet corn, johnnycake meal, and chowder. Theophrastus is nothing if not a chauvinist. He writes that "chowder has reached a peak in Little Compton, R.I., or rather down on Sakonnet Point . . . . I know of at least two people in town who have made a lifelong study of chowder, of which Louis Waite is one and I am the other."

Although Theophrastus offers loyal subscribers a twenty-page treatise on chowder (not to mention another page of afterthoughts), he does not print a recipe for clam chowder. So, until I hie me to Sakonnet Point and cajole him into feeding me, I won't be able to judge his chowder in the way I would like. But he is a most explicit expounder, and in essence, he seems to me to have defined a much-distorted and improvised-upon soup with clarity and rightminded passion. In particular, he is passionate about the clams. They must be quahaugs, he says.

Now if you happen to be in Little Compton or other parts of New England where people are brought up knowing that quahaug (also spelled quahog) is an Indian word denoting a large, hard-shelled clam, you will have no trouble getting the right clam. When Theophrastus g around to writing his book on chowder, will undoubtedly disclose to readers t his quahaug is the bivalve known to L naeus as *Mercenaria mercenaria*. It ha hard shell and a short neck, or siph unlike the soft shell and elongated neck the soft-shell, or steamer, clam (*M arenaria*). *M. mercenaria* goes by seve names other than quahaug. Most of th names refer in a rough way to the size (a therefore to the age) of the creature. T smallest are usually sold as littlenec Somewhat larger and salmon-fleshed the cherrystones. Both these varieties c be, and almost always are, served ra Larger, older and tougher hard-shells b efit from chopping and then light cooki In my experience, these large hard-she are sold in New England as quahogs. E in other places, they are billed as chowd clams. At any rate, I am sure that Th phrastus and I are both talking about t same clam, a native East Coast hard-sh with a shell about four inches or mo across.

Having acquired the correct clams, y must resist the urgings of the multitude recipe writers who call for steaming the open. To wit, Theophrastus: "The cla must be opened with a clam knife . . . a added later. A moment's thought will t why. When you steam the clams enou to open them, the clams are inevitabl cooked and have become little knots th cannot possibly impart their full flavor the chowder, no matter what you try to to them subsequently. Previously cook clams, in my opinion, also give an off f vor to a chowder."

Theophrastus does not bother to me tion that it is much easier to open b clams by steaming than by prying the apart with a clam knife. On the oth

Clam Chowder
(With thanks to Theophrastus and Cap'n Phil Schwind)

2 dozen chowder clams (hard-shelled clams, or quahaugs, not steamers, about 4 inches across)
1 piece salt pork about 2 inches square and ¼-inch thick
1 medium onion, peeled and chopped
2 medium Idaho potatoes, peeled and diced
1 quart milk

1. Rinse and brush the clams. Then chill. Cold relaxes the muscles that hold the shells together. To open, slide a stiff knife blade between the shells opposite the hinge. Slide the blade back and forth until the shells part easily. Collect clams and clam juice in a bowl.
2. Cut the salt pork into a fine dice and cook over medium low heat in a heavy skillet so as to render fat slowly. When the solid pieces are very brown, remove from heat, pick out the solid pieces with a slotted spoon, and reserve.
3. Sauté the onion until translucent in the fat rendered from the salt pork.
4. Simmer the potatoes in the milk until almost tender.
5. Chop the clams and simmer in their juice until heated through.
6. When ready to serve, combine all ingredients and heat through, but do *not* boil the milk after you have added the clams and clam juice. If the milk boils it will curdle.

Yield: 8 servings

and, he is surely correct about the superiority of starting with raw clams. He might also have mentioned that steaming clams inevitably adds water to their natural juices (known everywhere, even on the Rhode Island shore, as clam juice).

Actually, opening clams is not all that challenging if you remember to refrigerate the clams ahead of time. Cold relaxes their muscles. To open: rinse off any mud with cold water. Then grasp the clam with one hand by the hinge. Insert a clam knife (or other strong, short, wide-bladed knife) into the crack between the shells opposite the hinge. Run the blade back and forth until the clam gives up and can be easily opened the rest of the way by hand. It is efficient to open chowder clams over a bowl so that the juice is automatically collected. I feel sure that Theophrastus does it this way. He is also canny about the other chowder ingredients, holding out for real Idaho potatoes and thumping *Yankee Magazine* for a recipe that fancied up a clam chowder with thirteen "additives" ranging from carrots to butter, flour, and herbs. "A 'true' clam chowder," he says, "has nothing in it but quahaugs, salt pork, onions, potatoes and milk—no pepper, no salt, nor any other spices or herbs, no water, nor anything else, and if properly made—paradoxically—has a spicy flavor as if all those forbidden additives had been doused into it."

When he gets down to converting these unimpeachable principles into a workaday recipe, Theophrastus will probably also stress the importance of never boiling the chowder once the milk has been added. Boiled chowder curdles. Even then, a Theophrastean chowder has a remarkable, a unique flavor. As the man says, "There is nothing else that tastes like a 'true' chowder—the clams or quahaugs carry the melody—with the onions, potatoes and salt pork providing a modest but essential backup."

Too many variant recipes for New England clam chowder exist—and have existed for a century and more—for anyone, even Theophrastus, to be able to decontaminate the tradition and declare with certainty that his or hers is the authentic method. But if I had to choose—and I suppose I am choosing—what seems the purest, most essential version of New England's most famous regional recipe, I would certainly side with Theophrastus. He has logic on his side, and his chowder tastes better. A French chef might even find it sincere.

Raymond Sokolov is a writer with a special interest in the history and preparation of food.

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Catch of the Day

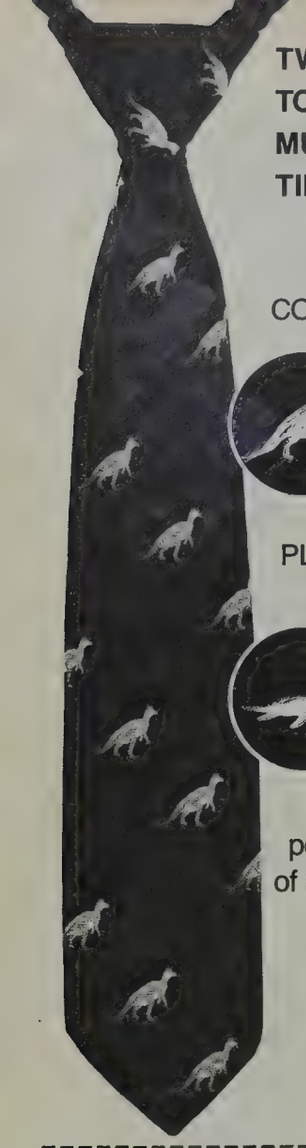
Photograph by
Mark Newman

Every July in southwestern Alaska, the chum salmon migrate up the McNeil River to spawn, and every brown bear for miles around shows up to catch them. The short northern summer is ending, and the bears are putting on the poundage to carry them through their hibernations. They converge on the McNeil and they eat, and they eat, and they eat.

It is the largest known gathering of brown bears in the world. As many as fifty may be in sight at any given time, eating, sleeping, or walking around. Dominant bears take the best fishing spots; when they've had their fill, lower-ranked bears can come in. Coastal brown bears belong to the same species as upland grizzlies, but bears living near the water tend to be larger—up to a thousand pounds.

Photographer Mark Newman spotted this six-foot bruiser standing in the shallows, going tooth and claw at a salmon. Given their druthers, the bears would just pick off the fish's skin or eat the roe. And although bears are not usually gregarious, the glut of salmon and the joy of eating appears to make even these for boding beasts treat their fellow creatures—even birds—with some forbearance. After skinning this salmon, the bear threw the rest the gull's way.

—Charles C. Mann



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Authors

Born on the island of Luzon in the Philippines, **Agnes Estioko-Griffin** (page 36) began participating ten years ago in a research project on the Agta hunter-gatherers of her native land. The Agta life style she observed challenged the widespread assumption that in such groups, men do the hunting and women do the gathering. In field research in the Philippines from 1980 to 1982, Estioko-Griffin (left) focused on this question, documenting the flexible division of labor described in this issue. More information about the Agta's subsistence activities and their environment is contained in a paper by her husband, P. Bion Griffin, in *Past and Present in Hunter Gatherer Studies,* edited by Carmel Schrire (Orlando: Academic Press, 1984). Several interesting views of women in hunting societies and their importance as providers can be found in *Woman the Gatherer,* edited by Frances Dahlberg (New Haven: Yale University Press, 1981). A staff archeologist at Hawaii's Department of Land and Natural Resources, Estioko-Griffin plans to undertake archeological investigations concerning the prehistory of the Agta, which stretches back at least 12,000 years.

In retirement in Carmel, California, husband and wife **Lovell and Libby Langstroth** (page 44) found new careers studying the ecology of the kelp beds of Monterey and Carmel bays. Now, at 69 and 64 years of age, respectively, they dive and photograph and lecture; travel to the Indo-Pacific coral reefs; and exhibit their photographs, which they develop in their own color lab. Their photographs of sea anemones were featured in the November 1984 issue of *Natural History,* and this not very retiring team is now recording a year of life in the kelp beds, from the peregrinations of its creatures to what Lovell Langstroth calls the "beautiful geometry" of the plant itself.

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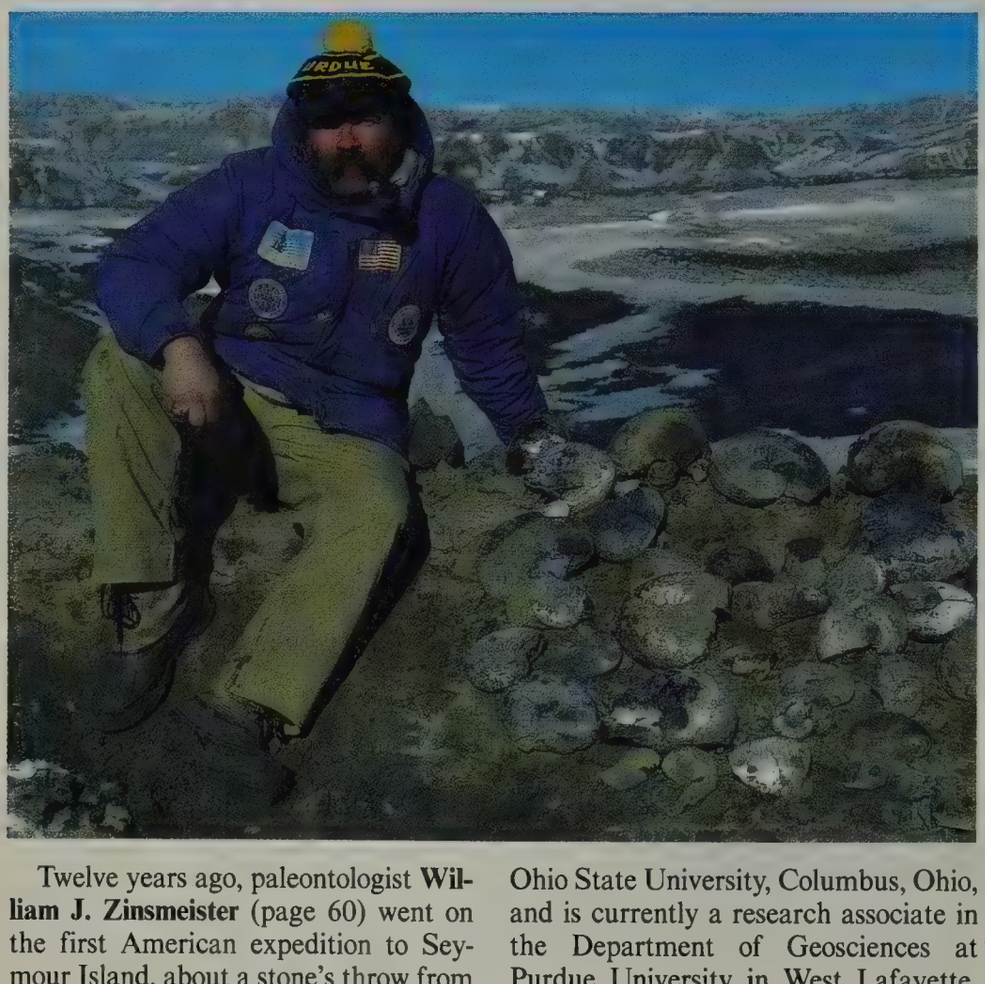

Twelve years ago, paleontologist **William J. Zinsmeister** (page 60) went on the first American expedition to Seymour Island, about a stone's throw from the Antarctic Peninsula, to investigate ancient fossils. He has since tracked down these fossils in the Arctic, the Antarctic, South America, New Zealand, and Australia and has made so many field trips he has lost count of them. Zinsmeister has a Ph.D. in geology from the University of California, Riverside. From 1974 to 1982 he was a resident scientist at the Institute of Polar Studies of Ohio State University, Columbus, Ohio, and is currently a research associate in the Department of Geosciences at Purdue University in West Lafayette, Indiana. Since his primary interest is prehistoric fossils, it seems entirely fitting that one of his hobbies is watching old movies on television. For those who would like to learn more about the evolution of flora and fauna in the Southern Hemisphere, he recommends *The Geological History of New Zealand and Its Life,* by C.A. Fleming (Auckland University, New Zealand, 1979).

Every year, the McNeil River Wildlife Preserve allows a limited number of photographers to shoot the bears. The preserve has two viewing areas, "just flat spots about twenty feet to a side," says **Mark Newman**, who took this month's "Natural Moment" there, using a Nikkormat ELW with a Nikor 500 f-8 reflex lens. Biologists accompany the photographers; if bears get too close, the scientists drive them off with rocks. They also carry shotguns, which, Newman says, "are practically never used." With writer-photographer Terry Domico, Newman is working on *Bears of the World,* a reference work that will appear in 1988. When not photographing wildlife, Newman works as a physician at North Care Minor Emergency Clinic in Anchorage, Alaska.

J.P. Myers (page 68) received his doctorate in zoology from the University of California, Berkeley, in 1979. Since then, his fieldwork has taken him from coastal California to Argentina, Chile, Peru, and the Alaskan Arctic—extremes also traversed by the migratory shorebirds that are his special interest. When Myers moved east to take up a post at the Academy of Natural Sciences in Philadelphia, where he is now an associate curator of ornithology, he soon tuned in to the huge annual shorebird influx at Delaware Bay. He finds this impressive but little-known natural history event one of "immense conservation value and great fun." Therefore, in addition to his present studies of the ecology of shorebirds, particularly sanderlings, and the population biology of horseshoe crabs, Myers is helping to coordinate the Delaware Bay system with other spring staging sites for Arctic-bound birds. The resultant International Shorebird Sister-Reserve System will be a hemisphere-wide chain of shorebird refuges. For further reading, Myers suggests *Shorebirds: Migration and Foraging Behavior,* edited by J. Burger and B. Olla (New York: Plenum Press, 1984) and Peter Matthiessen's *The Wind Birds* (New York: Viking Press, 1973).

Photograph by Frans Lanting

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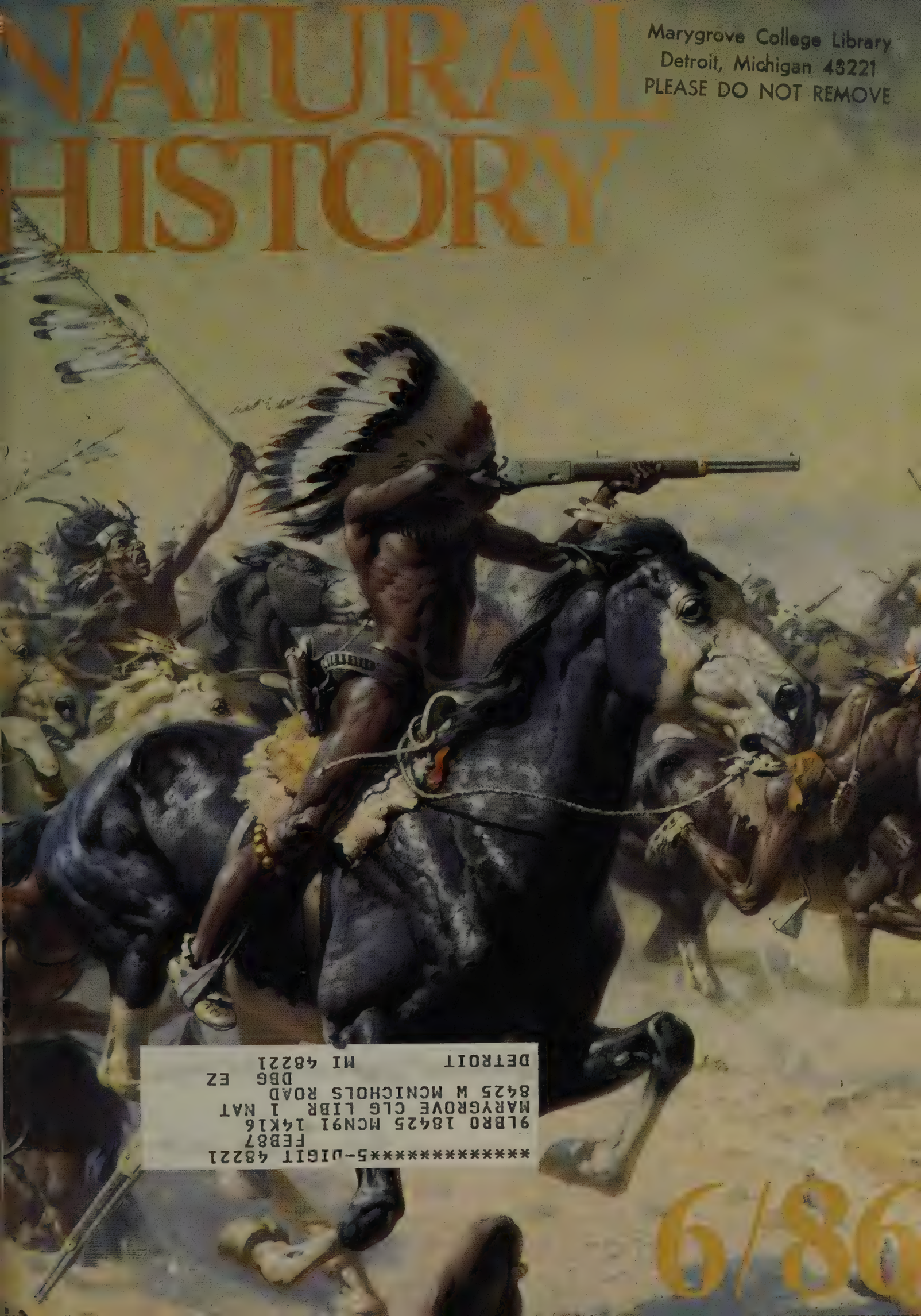

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Vol. 95, No. 6, June 1986

American Museum of Natural History, New York, N.Y.
Robert G. Goelet, President
Thomas D. Nicholson, Director
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4 A Naturalist at Large *Hal Whitehead*
Call Me Gentle

12 This View of Life *Stephen Jay Gould*
Fortitude from Heaven

20 This Land *Robert H. Mohlenbrock*
Blanchard Springs Caverns, Arkansas

24 Reviews *E. L. Schieffelin*
Asaro Valley Pilgrimage

28 Quake Replay in the Great Basin *Ross S. Stein and Robert C. Bucknam*
Along Great Basin faults, infrequent—but terrifying—earthquakes cause mountains to rise and valleys to fall.

36 The Panamanian Love Call *Michael J. Ryan*
A frog's reward for his singing may be an amorous female . . . or a hungry bat.

46 Post-mortem at the Little Bighorn *Douglas D. Scott and Melissa A. Connor*
The Indians had twice as many carbines as Custer's men.

56 Odd Couples of Suburbia *Frederick R. Gehlbach*
Why do female screech owls choose small mates?

70 Sky Reporter *Stephen P. Maran*
Off the Main Drag

74 Celestial Events *Thomas D. Nicholson*
Hooray for Mars

76 A Matter of Taste *Raymond Sokolov*
The Mountains Come to Manhattan

80 At the American Museum

82 The Natural Moment *Photographs by Martin W. Grosnick*
Soft-shoe on a Ewe

88 Authors

Cover: *A detail of* Custer's Last Fight, *by William R. Leigh. The 1939 painting in the Woolaroc Museum, Bartlesville, Oklahoma, overemphasizes the role of horses in the historic battle. Story on page 46.*

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Call Me Gentle

Contrary to their reputation for brutality, sperm whales observed in the Galápagos are timid and sociable creatures

by Hal Whitehead

The whales were enjoying a restful, social interlude. They lay at the sea surface, closely packed and parallel to one another, looking much like twelve floating tree trunks stripped of their branches. Once every day or two, sperm whales cease their usual commuting between the surface, where they breathe, and the 1,500-foot depths that are home to the large squid on which they feed. They then slow down, gradually glide toward one another, and form still, silent, and raftlike subgroups.

Ten of the twelve whales that we were approaching, adult females and immatures (whose sex cannot be determined), were roughly the size of our 33-foot-long sloop, the *Elendil,* but one, a mature male, was much larger, and the twelfth, another mature male, was vast. His gnarled and wrinkled back dwarfed the surrounding females much as an ancient oak overshadows saplings. We could hardly believe that the males and females were adults of the same species.

We were in the middle of a 2½-month-long study of the social organization of the sperm whales around the Galápagos Islands. The details of the interactions between large, adult, male sperm whales and the groups in which the females seem to travel were not known, and had become a source of controversy for scientists who try to examine sperm whale populations and "manage" their stocks. Several questions were unanswered: What size are the males that do the mating? Do they really form the "harems" of popular literature? Is there cooperation between males? And how long does their overlordship of a group last? Hours, months, years?

Tom Arnbom, our Swedish helmsman, carefully maneuvered the *Elendil* near the whales, to position it like a thirteenth member of their subgroup. We call the temporary assemblages of whales that form, separate, and re-form in different combinations at the surface "subgroups" to distinguish them from the longer-lasting groups of whales in constant association with each other over periods of at least several days and probably, in the case of females, many years. From my perch in a bosun's chair halfway up the mast, I watched as we slowly drifted closer

Tom Arnbo

Their high, broad, flat foreheads distinguish the sperms from all other whales.

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and closer to the whales. Bracing my feet against the *Elendil*'s cross-trees, I raised my camera. My objective was to take photographs that would show the whales lying parallel to the horizon. If the pictures were properly taken, we would later be able to estimate the lengths of the whales by making measurements on the negatives.

When we came within about 100 feet, the nearest whale, a female, turned. Her wrinkled back rolled slowly through the clear water, the tip of her left fluke broke the surface, and she headed directly toward us. Sperm whales are touchy creatures; they are easily startled if approached precipitately. But occasionally during our study, a sperm whale, often a young one, had taken a swing past the *Elendil,* stopping only five to ten feet away to stare briefly, before sliding down into the deep. These encounters were always slow paced and civil, so we had no qualms about this female.

Then, following the lead of the plucky female, the remaining eleven whales turned toward the *Elendil,* and began a steady approach. Seeing a row of the shiny, dark, bulbous heads of the sperm whales converge on our boat from about thirty feet away was impressive but not particularly disturbing—we had seen it several times during our studies. I watched the lead female glide slowly, and with no apparent movement of her flukes, a few yards beneath the *Elendil*'s stern. I then looked back at the next whale in line—the largest male. His broad, flat forehead was aimed toward the *Elendil.* His oil-filled "case" (the forehead above and in front of the skull), which forms the front third of a large male sperm whale, filled my vision. It was deeply scarred, probably from battles with other males. A chord of dread struck me as I noticed that the lower half of his forehead was white. Quotations from Melville's *Moby Dick* rang in my ears:

> It was the whiteness of the whale that above all things appalled me . . . .
>
> In the great Sperm Whale, this high and mighty god-like dignity inherent in the brow is so immensely amplified that gazing on it, in that full front view, you feel the Deity and the dread powers more forcibly than in beholding any other object in living nature. . . .
>
> The Sperm Whale is in some cases sufficiently powerful, knowing, and judiciously malicious, as with direct aforethought to stove in, utterly destroy, and sink a large ship; and what is more, the Sperm Whale has done it.

Behind the whales converging on the *Elendil,* but within our sight, was the island of Isabela, the largest in the Galápagos group. Descending from its cloud-shrouded summit lay Punta Essex, a dark lava flow. An American whaleship also named *Essex* had been rammed not far from our position by a large male sperm whale in 1816 and subsequently sank. The Punta Essex was thus a grim reminder o the danger of male sperm whales. But th male approaching us submerged suffi ciently to pass about three feet below th *Elendil*'s keel. For a few interminable sec onds the enormous animal seemed to flo beneath us, and then was past with n harm done.

This incident and others have dispelle in us Melville's image of the sperm whal as a vicious and malicious beast. In creat ing the character of Moby Dick, Melvill ignored the opinion of his major source o scientific information about whales, th English whaleship surgeon Thomas Beale Writing in 1839, Beale considered th sperm whale to be a "most timid and inof fensive animal." Incidents like the sinkin of the *Essex* were rare.

During the weeks that we spent wit sperm whales, the subjects of our researc showed themselves to be gentle animals They are usually shy but occasionally cur ous in the presence of humans and thei boats. They show no shyness, howeve with each other, displaying very sociabl behavior. Although adjacent sperm whales probably separate several hundre feet when feeding at depth, off the Ga lápagos they often appeared to form a lin several miles long, with the whales swim ming parallel to, and roughly abreast o one another. These ranks swept throug the deep ocean at a steady rate of two an one-half to three knots (about three to fou miles) per hour, for twenty-four hours o

Sperm whales dive almost 1,500 feet to feed on large squid, but surface about every forty minutes to breathe.

Bud Lehnhaus

Guess what. I slipped on the ice and fell. Me.
How am I going to live it down? And you know who saw me?
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more. Individuals surfaced about every forty minutes to breathe, but the formations advanced relentlessly.

When foraging about 1,500 feet beneath the surface, each individual made the characteristic, regular (about once per second) click of the sperm whale, which is almost certainly a form of echolocation. The jumble of clicks of a group of hunting sperm whales, which together sound like radio static, foretells approaching death for many squid, the whales' preferred food. But for us on board the *Elendil,* the clicks were an important key to the whales' position. We listened regularly to a directional hydrophone (an underwater microphone) and adjusted the *Elendil*'s course and speed depending on the direction and volume of the clicks. With our hydrophone we could tell the bearing of a clicking sperm whale from about five miles away, and thus were able to track groups of whales for days at a time.

Between forty-minute feeding bouts, the sperm whales remained at the surface breathing for about eight minutes. During these periods the whales seemed irresistibly drawn to one another; if two whales surfaced within a thousand feet, they usually sidled up to one another for companionship during their few minutes at the surface. The small calves, which did not dive deeply, were particularly active in joining the adults.

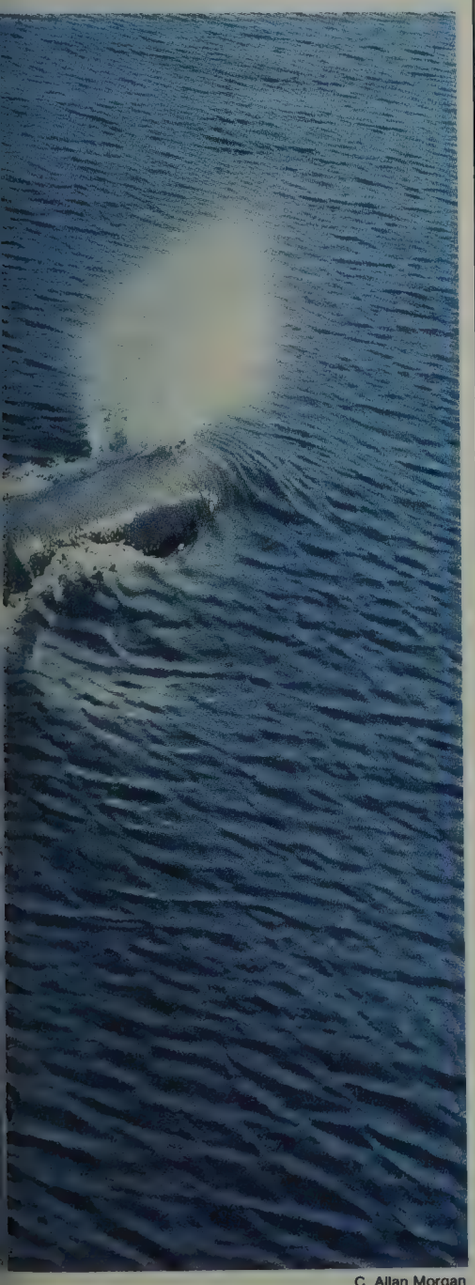
But it was during their social times, when subgroups of five to forty whales congregated at the surface for an hour or more, that the significance of their communal relationships was most apparent. Although from the deck of our boat the whales resembled a raft of inanimate logs, when seen beneath the surface they were revealed as extraordinarily flexible, tactile, and tender animals. Snorkeling behind the *Elendil,* we saw them turn gracefully to watch us, gently stroke one another with their small flippers, or nuzzle a smooth, bulbous brow against a vast wrinkled flank. Our underwater observations of whales were generally brief; we are not practiced divers, and there w always much to be done back on board t *Elendil*—data sheets to fill in, phot graphs to take, food to cook, and the my iad tasks of life at sea on a small boat squeeze in between the research and t few hours of rest each of us was allott every day.

Three of our crew of five (myself a two others), as well as the *Elendil* itse had been involved in the World Wildli Fund Indian Ocean Sperm Whale Stu between 1981 and 1984. During th project we had developed methods of fin ing, tracking, and studying sperm whal When it ended we wondered if the might not be a better location for the r search than Sri Lanka, our major stu area in the Indian Ocean. Sri Lanka h many advantages but it is extremely hot, swept by monsoons that make resear almost impossible for half the year, and sadly becoming embroiled in escalati racial violence. But its most significa disadvantage is a lack of large male sper

When the whales surface, they blow about once every fifteen seconds.

ales—during our months there, we had
n only three large adult males, and then
y briefly. At that rate it would take
rs to obtain any understanding of the
cial interactions between the large
les and the groups of females.

We examined maps of where the nine-
nth-century Yankee whalers had made
ir kills, and also looked at charts of
an weather conditions. The ocean area
t the whalers called the Galápagos
ounds immediately stood out in terms
the abundance of sperm whales there
d its prevalent calm, relatively cool
ather. The British had discovered the
lápagos Grounds during their late
hteenth century round-the-world ex-
rations. Capt. James Colnett of the
tish Royal Navy, who visited the Ga-
agos in 1793 and 1794, wrote: "Every
e was charmed with the place." The
w "saw spermaceti whales in great
mbers," and Captain Colnett recom-
nded the Galápagos Grounds to British
alers. His advice was followed, particu-



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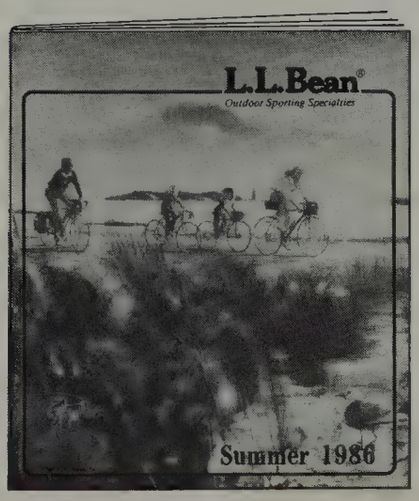

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larly by the stubby whaleships sailing from New Bedford, Nantucket, and other New England ports. During the first part of the nineteenth century, the Galápagos formed one of the Yankees' favorite whaling grounds. At that time, the whalers provided much of the Western world's oil, and the whales were remorselessly exploited. After 1850, presumably because sperm whale populations had been depleted, the whalers usually found the Galápagos "dry cruising."

Mercifully, the Galápagos seem to have escaped the attention of the ultraefficient, mechanized whalers of the twentieth century; consequently there is little recent information on the Galápagos Grounds. Some competent authorities warned us that we would be wasting our time cruising off the islands, that we would find few whales, and that even those would be far offshore. Other advisers were more optimistic. The only way to find out, of course, was to go there and see for ourselves. So in February 1985, we set sail from our temporary berth in France, bringing the *Elendil* across the Atlantic Ocean and the Caribbean Sea, and through the Panama Canal to reach the Galápagos. There, with excellent cooperation from the Charles Darwin Research Station in the Galápagos, we found conditions almost ideal for our research. The weather was placid, and considering that the equator runs right through our study area, the temperature was remarkably cool. Female sperm whales were there in large groups that were easy to track acoustically. And most important, large male sperm whales were often present. In 1798 Captain Colnett had written: "The situation I recommend to all cruizers, is between the South end of Narborough Island [now generally called Fernandina] and the Rock Redondo [Redonda]."

This region, where the underwater Cromwell Current, running eastward directly below the equator, is forced to the surface by the islands of Fernandina and Isabela, became the core area of our research. Groups of sperm whales would sometimes stray about a hundred miles to the south or west, but they were most numerous between Fernandina and Redonda. These waters provided a steady stream of surprises. Thick fogs, reminiscent of the Grand Banks of Newfoundland, alternated with a burning equatorial sun. We saw such polar animals as penguins and fur seals a few hours sail from clear, warm waters that were the home of flying fish and tropic birds.

For thirty nights we listened to the clicks of the sperm whales through our directional hydrophone, and for thirty days we watched their slanted exhal tions. Much of what we now know abo the social interactions of sperm whal comes from the analysis and identificati of photographs, tapes, and other data collected. But one incident that took pla while we were still at sea led to immedia insights.

Near the end of our study, the group whales we were following strayed mo than ninety miles out to sea west of t islands. It was midmorning, and t whales, arranged in an east–west rank se eral miles long, were clicking noisily a moving steadily southward. But they su denly became silent, and our crew me ber Amelia Brooks, whose turn it was to up the mast in the bosun's chair, spott them clumped together in two large su groups a few thousand feet away. This w an unexpected and dramatic change behavior. Sperm whales usually sh gradually from the hunting/spread-ou clicking phase of their behavior to the cial/congregated/silent phase during hour or two, with fewer and fewer clic being heard and the subgroups becomi steadily larger. The sudden silence and t coalescing of subgroups was most u usual, but its cause was soon appare "Orcas," Amelia shouted from her per up the mast.

Some powerful twenty-foot-long orc often called killer whales and probably t only serious predator that sperm whal face, were circling the huddled sperm For three hours we watched the orcas pu sue the sperms. The twenty-five or sperm whales remained packed closely gether and tried to keep themselves faci directly toward the nearest orcas. Th began clicking rapidly and with great tensity as the orcas got closer. The spe whale's head, with its powerful jaws a sophisticated acoustic system, is probab the animal's least vulnerable part. P haps realizing this, the orcas, in subgrou of two to five, darted around the flank the massed sperm whales to attack the from behind. The larger sperm whal turned, trying to keep the orcas in front them. We watched the two speci maneuvering like chess pieces. There w one small sperm whale calf. Like a ch player's king, it was kept in the protect center of their group, presumably the s est place. By contrast, the only large ma sperm whale with the group usually hu behind. Was he guarding their vulnerab rear or just tagging along? The two lar male orcas also hung back, taking lit part in the action. Most of the interacti at close quarters between the two spec took place underwater. After the sk mishing ended, we saw some fresh op

)unds on several sperm whales, but since ne were particularly deep, it seemed likely that any of the sperms were badly ured. The whole fray appeared to contute a kind of test in which the orcas reatened the sperms to see if there were y particularly vulnerable ones that uld then be assaulted in force.

The end of the incident was most intering. The sperm whales began turning in ht circles, the whole mass revolving evy two to three minutes. Perhaps the cas now realized the futility of their atck, for they began to move off to the st. When the orcas were about 1,500 et away, the sperm whales made their ove. They fell totally silent and started aveling fast to the east, remaining in eir compact subgroup. For six hours ey maintained a speed of five and a half ots (about six to seven miles) per hour, d we followed after them. With the exption of the one large male, which fell hind for a while, the sperm whales reained in a tightly packed group throughit the entire flight. That was an unparalled event in our experience with sperm hales. They were also uncharacteristilly silent, again with the exception of the g male, which broke the silence briefly ith his slow, distinctive click.

The attack and subsequent flight were not only instructive in showing how the top oceanic predator (the orca) attacks what is probably its most formidable prey, but also contained some important hints about the relationship between the large male sperm whale and the group to which he was attached. The male made a considerable effort to stay with the group, although he did not seem to be a fully integrated member or, in any sense, to be leading it. The large sperm whale also broke the silence of the other sperm whales, thereby perhaps disclosing their presence to the predatory orcas.

When night came, the silent sperm whales continued eastward, but without any clicks for us to hear, our directional hydrophone was useless, and we could only continue to sail eastward, hoping that the whales would maintain their course. In the morning, eighty-five miles east of the site of the orca attack, and close to the shore of Isabela Island, we found sperm whales—a large male and some females. But were they the same whales?

Since returning from the Galápagos, crew member Tom Arnbom has been poring over the many hundreds of photographs we took in an effort to identify individual whales. Using these pictures he has identified 214 females and immatures. We clustered these whales into thirteen "schools," which the *Elendil* had followed for a few days and then lost, to be picked up perhaps a week or a month later. Tom has also identified seven adult males that stayed with a particular school of females for a few hours but, exhibiting only transient fidelity, were found a few days later attending other females. And the fugitives from the orca attack? The male that we encountered the morning after the attack was indeed the same one that had taken the rear guard against the orcas, but during the night he had parted from the females in the subgroup and had taken up with a different school.

Buried in our photographs, tapes, and data sheets are more insights into the social system of sperm whales. Analysis of the material is slow, but fascinating, work. At the end lies our personal reward. We plan to return to the Galápagos Grounds in December of this year, to sail and swim again with the gentle sperm whale.

Hal Whitehead is a sailor with a Ph.D. in zoology from Cambridge University in England. He is now in the Biology Department at Dalhousie University in Nova Scotia, Canada.

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Astronomy, too, can be a "messy" science with planets "more like organisms than billiard balls"

by Stephen Jay Gould

When Miranda, confined for all her conscious life on Prospero's magic island, saw a group of men for the first time, she exclaimed, "O, wonder! How many goodly creatures are there here! How beauteous mankind is! O brave new world, that has such people in't" (the source, of course, for Aldous Huxley's more sardonic citation). Now, almost 400 years after Miranda spoke through Shakespeare, we have returned the favor, gazed for the first time upon Miranda and found her every bit as wonderful—"so perfect and so peerless . . . she will outstrip all praise and make it halt behind her."

Prospero used all his magic to import his visitors by tempest. We have seen Miranda, the innermost large moon of Uranus, through the most stunning feat of technical precision in all our history. Ariel himself, Prospero's agent of magic (and also another moon of Uranus), would have stood aghast. For we have sent a small probe hurtling though space for nine years, boosting it with the gravitational slings of both Jupiter and Saturn toward distant Uranus, there to transmit a signal across two billion miles and three light-hours, showing the face of Miranda with the same clarity that Prospero beheld when he gazed upon his daughter's beauty and exclaimed, "Thou didst smile, infused with a fortitude from heaven."

It is easy to wax poetic about this feat (especially with a little help from the Bard himself). *Voyager*'s data from Jupiter, Saturn, and now Uranus have supplied more scientific return for expended output than anything else that space exploration ever dared or dreamed. In the chorus of praise, however, we have not always recognized how much this new information has transcended the visually dazzling—how deeply our *ideas* about the formation and history of the solar system have been changed. This confluence of aesthetics and intellect must be celebrated above all—and I should like to record my delight by thoroughly repudiating an early essay in this series (March 1977) as an illustration both of our new understanding and of the vital generalization emerging from it.

My story is the tale of an old and eminently reasonable hypothesis, proposed long ago and beautifully affirmed by the first explorations of other worlds—our moon, then Mercury, and finally Mars. Then, at the height of its triumph, the theory begins to unravel, first at the moons of Jupiter, then at the surface of Venus, and finally and irretrievably, in the face of Miranda.

The initial hypothesis sought to explain the surfaces (and inferred histories) of rocky planets and moons as simple consequences of their differences in size. Why, in particular, is the earth so different from the moon? Our moon is a dead world, covered with impact craters that have not eroded away since their formation, often billions of years ago. The earth, by contrast, is a dynamic world of relative smoothness.

This difference, we assume, is a result of historical divergence, not initial disparity. Billions of years ago, when the planets were young and our portion of space still abounded with debris not yet swept up in planets and moons, the earth must have been as intensely cratered as the moon. The current difference is therefore a result of the moon's retention and the earth's obliteration of their early histories. Why the difference?

On earth, both internal and external "machines" recycle the landscape on a scale of millions of years. The atmosphere (external machine) generates agents of erosion—running water, wind, and ice—that quickly obliterate the topography o any crater. Yet even without rain an wind, the earth's internal activity of volca nism, earthquakes, and ultimately, o plate tectonics itself would eventually dis aggregate and erase any old topography Surfaces do not last for billions of years o an active planet. But neither machin works on the moon. With no atmosphere erosion proceeds (even in geological time at a snail's pace. Likewise, the moon is rigid body with a crust 600 miles thick Moonquakes do not fracture the lunar sur face and volcanoes do not rise from th tiny molten core.

The earth's activity and moon's silenc are consequences of a single factor—size Large bodies have much lower ratios o surface to volume than small bodies of th same shape, since surfaces (length × length) grow so much more slowly tha volumes (length × length × length) as siz increases. Our planet powers its two ma chines by low surface to volume ratios The earth generates heat (by radioactiv ity) over its relatively large volume an loses it through its relatively small sur face—thus remaining hot and activ enough to propel plate tectonics. Th moon, by contrast, and by virtue of it higher surface to volume ratio, long ag lost most of its internal heat and solidifie nearly throughout. Likewise, the earth large mass generates enough gravity t hold an atmosphere and power its externa machine, while the moon lost any gase once produced.

As planetary exploration began, thi "size dependent" theory of planetary sur faces and their histories received its firs tests and passed elegantly. The firs photos of Mercury showed nothing bu craters—as expected for a body just abou the same size as our moon.

Mars posed a clearer and more crucia

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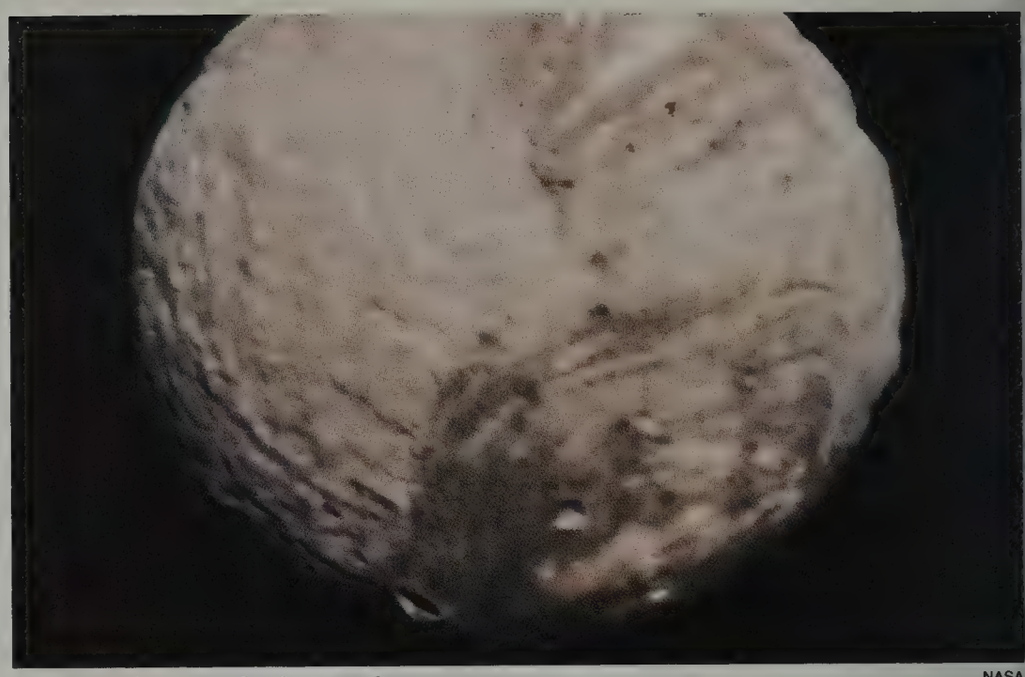

NASA

Voyager *photograph of Miranda*

test. As a planet about midway in size between the earth and moon, it should preserve some of its early topography, but also display the action of weak internal and external machines. The *Surveyor* flyby and *Viking* landings affirmed this prediction. The surface of Mars is about 50 percent cratered. The rest shows signs of erosion, primarily by winds today (dune fields and etched boulders) and by running water in the past (now frozen), and internal churning more limited than on the earth. Most intriguing are signs of incipient (and then failed) plate tectonics—as though the Martian crust is pliant enough to fracture, but too rigid to move.

At this point in space exploration, I felt confident enough to write an essay extolling the size hypothesis as a sufficient and elegantly simple explanation of planetary surfaces and their histories. Contrasting the earth with the smaller bodies then known, I wrote (in March 1977) that "the difference arises from a disarmingly simple fact—*size itself, and nothing else*: the earth is a good deal larger than its neighbors."

The first test after my essay appeared would be *Voyager*'s flyby of the so-called Galilean satellites of Jupiter—the four moon-sized rocky bodies that, by the size hypothesis, would surely be intensely cratered worlds, cold and dead. Thus, I waited with confidence as *Voyager* approached Io, the innermost moon of Jupiter. The first photos, distant and fuzzy, revealed some circular structures initially read as craters. Well and good. But the next day brought sharp photos, and evoked both wonder and surprise. The circles were not craters, but giant volcanoes, spewing forth lakes of sulfur. In fact, not a single crater could be found on Io, the most active satellite in the solar system. Yet, as a body smaller than our moon, it should have been cold and cratered.

The explanation now offered for Io's intense activity had been predicted just a few days before the photos arrived. Io is so close to giant Jupiter that the interplay between Jupiter's gravitational tug and the reverse pull of the three other large satellites from the opposite side keeps the interior of Io fluid enough to resist rigidification.

As this information arrived, I could only stand by in awe and reflect that Io had been misnamed. The four Galilean satellites honor some of Jove's many lovers—an ecumenical assortment including his homosexual partner Ganymede; the nymph Callisto; and Europa, the mother of King Minos. Io, the fallen priestess, was changed to a heifer by jealous Hera, afflicted with a gadfly, and sent to roam Europe, where she forded (and indirectly named) the Bosporus (literally, the cow crossing) and finally emerged, human again, in Egypt. I thought that this innermost moon should be renamed Semele, to honor another lover who made the mistake of demanding that Jove appear to her in his true, rather than his disguised (and muted), human form—and was immediately burned to a crisp.

Is the size hypothesis therefore wrong because Io violated its prediction? The principle of surfaces and volumes, as a basic law of physics and the geometry of space, is surely correct. Io does not challenge its validity, but only its scope. The size hypothesis does not merely claim that the surface to volume principle operates—for this we can scarcely doubt. The hypothesis insists, rather, that the surface to volume principle so dominates all other

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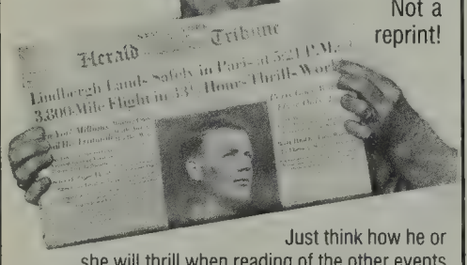

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potential forces that we need invoke nothing further to understand the history and topography of rocky planetary surfaces. Io does not refute the principle. But Io does prove dramatically that other circumstances—in this case proximity to opposing gravitational sources—can so override the surface to volume principle that its predictions fail or, in this case (even worse), are diametrically refuted.

Planetary surfaces lie in the domain of complex historical sciences, where modes of explanation differ from the stereotypes of simple and well-controlled laboratory experiments. We are not trying to demonstrate the validity of physical laws. Rather, we must try to assess the relative importance of several complex and interacting forces. The validity of the surface to volume principle was never at issue, only its relative importance—and Io has challenged its domination.

We must therefore know, in order to judge the size hypothesis, whether Io is a lone exception in a singular circumstance or a general reminder that the surface to volume principle is only one among many competing influences—and therefore not the determinant of planetary surfaces and their history. The test will not center upon arguments about the laws of physics, but upon observations of other bodies, for we must establish, empirically, the relative importance of a hypothesis that worked until *Voyager* photographed Io.

Venus was the next candidate. Our sister planet, although closer to us than any other, had remained shrouded (literally) in mystery by its dense cover of clouds. But Russian and American probes have now mapped the Venusian surface with radio waves that can penetrate the clouds, as wavelengths in the visible spectrum cannot. Results are ambiguous and still under analysis, but proponents of the size hypothesis can scarcely react with unalloyed pleasure. Venus is just about our size and should therefore, by the surface to volume hypothesis, be as active as the earth. Venus, to be sure, is no dead body. We have seen high mountains, giant rifts, and other signs of extensive tectonic activity. But Venus also seems to maintain too much old and cratered terrain for a body of its size, according to the principle of surfaces and volumes alone.

Scientists have advanced many explanations for the difference from earth. Perhaps tidal forces generated by the moon's gravity keep the earth in its high state of geological flux. Venus has no satellite. Perhaps the high surface temperature of Venus, generated by a greenhouse effect under its dense cover of clouds, keeps the surface too pliable to form the thin and rigid plates that, in their constant motion, keep the earth's surface so active.

As the size hypothesis toppled on Io and Venus, *Voyager* moved toward Uranus and a final test. One exception could be just that—purely exceptional. Venus is not fully resolved and not clearly contradictory in any case. Three in a row, however, might be fatal.

By this time, buffeted by Io and Venus, I was holding out little hope for the size hypothesis (and also wishing that the *Rubaiyat* had not spoken so truly about the moving finger, and that the editors of this fine magazine might deep-six in retrospect all copies of their March 1977 issue). In fact, anticipating final defeat for that elegantly simple proposal of earlier years, I actually managed to turn disappointment into a modest professorial coup. I have long believed that examinations have little intellectual value, existing only to fulfill and ever so imperfectly at that, any large institution's need for assessment by number. Yet, for the first time, the moons of Uranus allowed me to ask an examination question with some intellectual interest and integrity.

I realized that the final examination for my large undergraduate course had been set for the morning of January 24, at the very hour that *Voyager* would be relaying photographs of Uranian moons to earth. I therefore predicted that Miranda, although the smallest of five major moons, would be most active among them, and asked the students to justify (or reject) such a speculation—though the conjecture itself is absurd under the size hypothesis with its evident prediction that Miranda, as the smallest moon with the highest surface to volume ratio, should be cratered and devoid of internal activity. I asked the students:

As you take this exam, *Voyager II* is sending back to Earth the first close-up pictures of Uranus and its moons . . . . On what basis might you predict that Miranda, although the smallest of these moons, is most likely to show some activity (volcanoes, for example) on its surface? We will probably know the answer before the exam ends!

(When I first wrote the exam in early January, I couldn't even provide my students with the moons' diameters, for they had not yet been measured precisely, though we knew that Miranda was smallest. Between writing and administering the exam, *Voyager* measured the diameters, and we rushed to the printers with an insert. Science, at its best, moves very quickly indeed.)

So I was ready for the final undoing of the size hypothesis, but not for the actua

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result of Miranda's countenance. The conjecture of my question turned out to be quite wrong. I had been thinking of Io and the gravity of a nearby giant planet. Since Miranda is closest to Uranus, I supposed that it might be lit with modern volcanoes. But no volcanoes are belching forth sulfur, or anything else, on Miranda. The actual observations, however, spoke even more strongly against the size hypothesis and its prediction of a cold, cratered world.

I had made one good prediction, probably for the wrong reason: Miranda is the most geologically active of the Uranian moons, despite its small diameter of but 300 miles. (The moons of Uranus, outdoing even the mythic splendor of Jupiter's satellites, bear lovely Shakespearean names—in order from Uranus out: Miranda, Ariel, Umbriel, Titania, and Oberon. In addition, *Voyager* has discovered at least ten additional and much smaller moons between Miranda and the planet's surface.) The first photos of Miranda stunned and delighted the boys in Pasadena even more than her namesake had mesmerized Ferdinand on Prospero's island. Laurence Soderblom, speaking for the *Voyager* imaging team, exclaimed: "It's just mind boggling . . . . You name it, we have it . . . . Miranda is what you would get if you can imagine taking all the bizarre geological features in the solar system and putting them on one object." A brave new world, indeed. So much for the size hypothesis and its uniform blanket of craters.

Moreover, all the Uranian moons are surprisingly active (except for Umbriel, odd man out in more ways than one, as the only non-Shakespearean entry) in a gradient of increasing turmoil from the outermost king of *Midsummer Night,* to the innermost daughter of the *Tempest*. "As you move closer to Uranus," Soderblom added, "we see an increasing ferocity, as though these bodies have been tectonically shuffled in a cataclysmic fashion."

I must save the details for another time since results have not yet been published beyond initial press reports. But, for starters, the surface of Miranda is a jumble of frozen geological activity—long valleys, series of parallel grooves, and blocks of sunken crust. Most prominent, and also most notable and curious because they have no clear counterpart on other worlds, are three structures that seem related in their formation. One has been dubbed a stack of pancakes, the second a chevron, and the third a race track. They are series of parallel grooves, or cracks, shaped to different forms according to their nicknames and full of evidence for massive slumping, rifting, and cliff making.

In short, Io failed the size hypothesis by its position too close to Jupiter. Venus may not conform by the particular history that left it moon free and cloud covered. Miranda has failed, we know not why, by showing signs of a frantic past when the hypothesis predicted a passive compendium of impacts. The physical principle invoked by the size hypothesis—the law of surfaces and volumes—is surely correct, but not potent enough to overwhelm other influences and lead to confident predictions by itself. As we learn more and more about the historical complexity of the heavens, we recognize that where you are (Io) and what you have been (Venus and Miranda) exert as much influence over a planet's surface as its size. After its initial success for our moon, Mercury, and Mars, the size hypothesis flunked all further tests.

The story of a theory's failure often strikes readers as sad and unsatisfying. Since science thrives on self-correction, we who practice this most challenging of human arts do not share such a feeling. We may be unhappy if a favored hypothesis loses or chagrined if theories that we proposed prove inadequate. But refutation almost always contains positive lessons that overwhelm disappointment, even when (as in this case) no new and comprehensive theory has yet filled the void. I chose this tale of failure for a particular reason, not only because Miranda excited me. I selected it because the replacement of a simple physical hypothesis with a recognition of history's greater complexity teaches an important lesson with great unifying power.

An unfortunate, but regrettably common, stereotype about science divides the profession into two domains of different status. We have, on the one hand, the "hard," or physical, sciences that deal in numerical precision, prediction, and experimentation. On the other hand, "soft" sciences that treat the complex objects of history in all their richness must trade these virtues for "mere" description without firm numbers in a confusing world where, at best, we can hope to explain what we cannot predict. The history of life embodies all the messiness of this second, and undervalued, style of science.

Throughout ten years of columns firmly rooted in this second style, I have tried to suggest by example that the sciences of history may be different from, but surely not worse than, the sciences of simpler physical objects. I have written about a hundred historical problems and their probable solutions, hoping to illustrate a methodology as powerful as any possessed by colleagues in other fields. I have tried to break down the barriers between thes two styles of science by fostering mutua respect.

The story of planetary surfaces illus trates another path to the same goal o lowering barriers. The two styles are no divisible by discipline into the hard sc ences of physical systems and the soft sc ences of biological objects. All good scien tists must use and appreciate both style since large and adequate theories usuall need to forage for insights in both physic and history. If we accepted the rigid d chotomy of hard and soft, we might argu that as physical bodies, planets shoul yield to predictive theories of the har sciences. The size hypothesis represente this mode of explanation (and I was be guiled by it before I understood histor better)—a simple law of physics to regu late a large class of complex objects. Bu we have learned, in its failure, that planet are more like organisms than billiar balls. They are intricate and singular boc ies. Their individuality matters, and siz alone will not explain their surfaces. W must know their particularities, their earl histories, their present locations. Planet are physical bodies that require historica explanations. They break the false barrie between two styles of science by forcin the presumed methods of one upon th supposed objects of the other.

Finally, we should not lament that sim ple explanations have failed and that th "messy" uniqueness of each planet mus contribute to its resolution. We might de spair if the individuality of planets dashe all hope for general explanation. But th message of Io, Venus, and Miranda is no gridlock, but transcendence. We thin that we understand Io, and we strive t fathom the moons of Uranus. Historica explanations are difficult, damned inte esting, and eminently attainable by hu man cleverness. Whoever said that natur would be easy?

Prospero, after saving his foes from th tempest, asserts that he cannot relate th history of his life too simply, for "tis chronicle of day by day, not a relation for breakfast." The tale is long and intricat but fascinating and resolvable. We ca also know the richness of history in sc ence. Proper explanation may require tapestry of detail. Our stories may reca the subtle skills of Scheherazade rathe than the crisp epitome of a segment "Sixty Minutes," but then who has eve been bored by Sinbad the Sailor or Ala din's magic lamp.

Stephen Jay Gould teaches biology, geo ogy, and the history of science at Harvar University.

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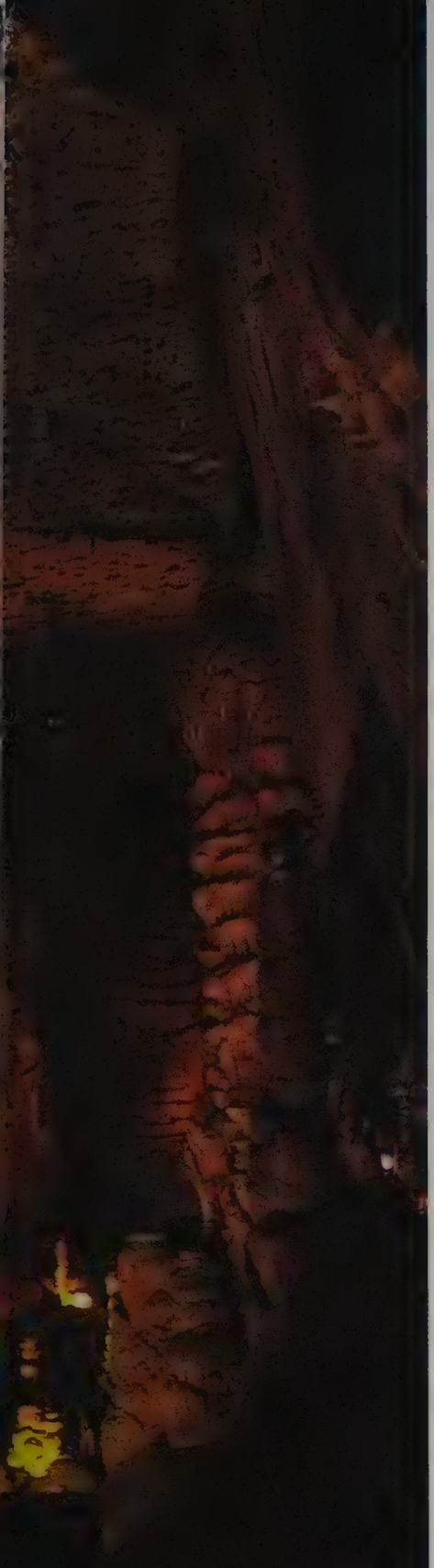


Blanchard Springs Caverns, Arkansas

by Robert H. Mohlenbrock

Geological formations of varied shapes and, sometimes, gigantic size make Blanchard Springs Caverns one of the most unusual attractions administered by the national forest system. The caverns are a product of the same forces that molded the topography in Arkansas's Ozark National Forest.

The caverns had their beginning perhaps seventy million years ago, after an ancient sea bed uplifted. The sea bed consisted of limestone, or calcium carbonate, derived mostly from the shells of small marine organisms. Rain fell on the newly exposed limestone, entering small cracks created by frost action and earth movements. Because it incorporated carbon dioxide from the atmosphere, the rainwater was actually a weak solution of carbonic acid, which converted some of the limestone to water-soluble calcium bicarbonate. As a result, the limestone began to dissolve away.

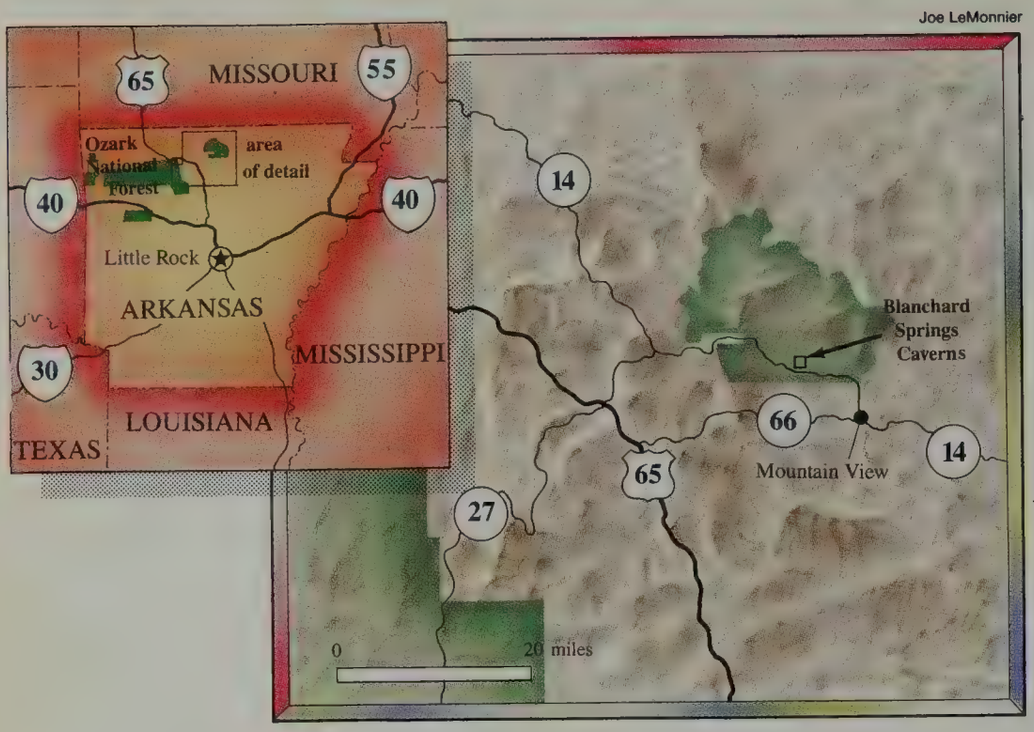
Caverns are usually formed only where dissolved limestone is carried off by rapidly moving water. In effect, nearly every limestone cave is (or was) an underground waterway. Sinkholes—bowl-shaped depressions where water drains into the earth—often develop at the surface in association with caverns. Sometimes the sinkhole opening into a cave is small and becomes clogged, so that the sink fills, forming a natural pond. In other cases, the opening is a vertical shaft into the cave through which water enters, eventually joining an underground river that flows between the layers of limestone. This is what happened at Blanchard Springs millions of years ago, with the water surfacing as a gushing spring several miles away.

After thousands of years, during which the rushing water carved underground chambers, the river shifted into a deeper channel. Dripping water entered the drained chambers, beginning a process of deposition that eventually built up stalactites, stalagmites, and other formations known collectively as dripstones, or speleothems. Later the river shifted again, leaving a second, younger set of chambers.

Large speleothems take millions of years to form. As droplets of water laden with dissolved calcium bicarbonate evaporate on the ceiling of a cave, they leave solid nuclei of limestone. Where this process is repeated at a single point, a stalactite begins to grow. At first, water runs through a small opening in the center of the dripstone, depositing calcium carbonate at the tip. Such a hollow stalactite is called a soda straw. Eventually, the soda straw becomes plugged and the water trickles down the outside, creating the stalactite's characteristic icicle shape. Because the water source for a stalactite is concentrated at a point on the cave ceiling, the stalactite is usually circular in cross-section. Where a crack in the ceiling results instead in an irregular distribution of water, thin sheets of dripstone—known as draperies—develop.

Water dripping off the end of a stalactite and striking the cave floor also has a chance to evaporate, creating a stalagmite. Stalagmites never have a central opening, have rounded tips, and have large, irregularly-shaped bases caused by the splash. When stalactites and stalagmites grow to meet each other, columns are formed. The largest such column in Blanchard Springs Caverns is sixty-five feet tall.

Sometimes dripstone builds up in



Blanchard Springs Caverns

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sheets that cover walls and older formations. This feature is called flowstone. Along underground pools and streams, intricate corallike ridges, called rimstone terraces, build up. All of these formations are plentiful along Blanchard Springs Caverns' two underground trails, which were opened to the public in the 1970s. Some are found in impressive hollows, such as the Cathedral Room, a cave 1,150 feet long and 180 feet wide.

Far less apparent than the geological formations is the life in the caverns. Green plants—mosses and algae—live only near the cave entrance or near the lamps that have been placed along the two trails. Fungi, which need organic matter to grow on, are rare in the caverns.

The animals that make use of Blanchard Springs Caverns range from those that live primarily outside but enter the cave from time to time to those that must spend their entire lives in the cave. Mole crickets are conspicuous among the creatures that freely enter the cave from outside. In contrast, the cave salamander, an orange amphibian with black speckles, rarely ventures "outdoors." And far away from the entrance to Blanchard Springs Caverns, where temperatures are uniform and blackness reigns, dwell an assortment of animals so adapted to their secluded habitat that they can never leave it. These include a white cricket, several crustaceans, and the Ozark blind salamander. Because they live in total darkness, these organisms need neither sight nor pigment; in addition to being blind, all are white or transparent.

One animal whose life cycle is heavily dependent on caves such as Blanchard Springs Caverns is the gray bat, an endangered species that lives only in a few southern states. The creature is about five inches long, has a wingspan of up to thirteen and one-half inches, and generally weighs less than one-half ounce. Because of disturbance of their habitat, including vandalism in some of their caves, the gray bat population has been drastically reduced during recent years.

Gray bats hibernate in mixed-sex co nies, choosing their winter caves by ea September. After the adults mate, the males enter hibernation immediately. T males join them after several more wee of feeding to replenish their depleted supplies. In the past, as many as 5,0 of these bats hibernated at Blancha Springs Caverns, but Michael Harvey noted authority on Arkansas bats, count only 150 there in February 1979, and o 33 in December 1985.

The females emerge from hibernati in late March and become pregnant fr the sperm stored in their bodies. Ma and juveniles emerge by mid-May. Af giving birth to single young in early Ju the females select a warm cave for t summer, where they congregate into maternity colony. Males and juvenile males form bachelor colonies in near caves. During the migration to the su mer caves, two to twenty miles away fr their winter quarters, the bats' food serves are at their lowest, and this is wh many die.

Blanchard Springs Caverns curren houses a summer bachelor colony of ab 18,000 bats, which forage up to twe miles away each night for insects. Mich Harvey points out that these bats consu about 130 pounds of insects each night, more than 13 tons during a single summ This is one of the ways in which the und ground caverns make their presence fel the forest land above.

"This Land" highlights the biologi phenomena of the 153 U.S. national f ests. Robert H. Mohlenbrock is dist guished professor of botany at South Illinois University at Carbondale.

Merlin D. Tuttle; Bat Conservation Interna

Blanchard Springs Caverns houses 18,000 gray bats during the summer.

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Asaro Valley Pilgrimage

by E.L. Schieffelin

When Kenneth Read published *The High Valley* in 1965, it was one of the few (and still one of the best) personal accounts of anthropological fieldwork available. It depicted life among the Gahuku-Gama people of the highlands of Papua New Guinea through a series of vivid portraits of Gahuku men Read had come to know, narrated partly in terms of the shared experiences through which he came to know them. Written as a kind of ethnographic memoir, the book revealed how the gathering of ethnographic material may be as much a personal journey of self-discovery for the ethnographer as it is a piece of scientific research. Indeed, Read implies, good fieldwork depends upon the ability of the researcher to undergo such personal change. "Unlike other experimental procedures in dealing with human material," he writes, "[in anthropology] the subject of the experiment is the observer himself, not those from whom he or she hopes to learn."

RETURN TO THE HIGH VALLEY, by Kenneth E. Read. *University of California Press, $18.95; 269 pp., illus.*

From that first book, Read's fans will remember the vivid characters he portrayed: the proud and volatile Goluwaizo, jailed for striking an old woman who had annoyed him; Asemo, the thoughtful, forward-looking youth forced to undergo a brutal initiation; Tarova, the ten-year-old bride; and Makis, the arrogant and flamboyant, but also subtle and perceptive Big Man, who became Read's closest friend. One departed from these characters at the end of the book with the same sense of regret, relief, and unfinished business as did the anthropologist himself when h was forced by illness to leave the field.

Read didn't return to the Gahuku Gama for thirty years. *Return to the Hig Valley* chronicles his experience—part r search, part personal pilgrimage—in r turning to Makis's village of Susuroka i 1981 and 1982. Makis was dead, killed i a road accident in 1965, but his two wi ows and a son and a daughter now in the thirties welcomed Read as a returnin member of the family. Read discovere that he was one of the few people wh could still remember the old days whe tribal fighting had barely ended and th rituals and beliefs of the secret *nam* men's cult were still an important focus cultural concern. People under thirty-fiv years old had grown up without any e perience of precontact Gahuku cultur Indeed, Read found that young peop had very little interest in how their elde

Gahuku-Gama man in the village of Susuroka in 1981

Kenneth E. R

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had once lived or in what they had done.

In the 1930s and 1940s, prior to pacification, warfare and fighting among the Gahuku clans had been endemic in the valley. The only career available to a young man was that of a warrior. His job was to guard his relatives and his community against the raids of others and to pursue vengeance against those who injured his own. The image of the warrior, glorifying an arrogant, fierce, and violent-tempered masculinity was the dominant cultural ideal. Traditional Gahuku ritual was designed to toughen warriors and remove from them any weakening influence picked up from association with women. Warriors purified and steeled themselves as fierce fighters by forcing sharp wads of spear grass up their nostrils to bleed their noses, and by swallowing bent strips of cane to make themselves vomit. Boys were forcefully initiated into these practices in a traumatic rite of passage when they were about fifteen. The beliefs entailed in the warrior ideology fostered a deeply ambivalent relationship between the sexes, which manifested itself in the men's domineering misogyny. Indeed, to protect their strength from the debilitating influences believed to emanate from women, men traditionally slept in the men's cult house, while their wives slept separately in smaller houses around the village.

When the Australian colonial government put an end to warfare in the 1940s, the Gahuku abandoned their warrior ideology and its ritual practices within a relatively short time—without significant encouragement from either the colonial government or the missions. The central and deeply seated cultural beliefs and practices that had shaped their major moral values, defined their sense of self, and outlined the basic relationships between the sexes were simply thrown over and abandoned with the cessation of warfare. Without a backward glance, the Gahuku moved forward to grasp at whatever opportunities the new colonial dispensation had to offer. Former warriors who had practiced the rituals all their lives and were proud of their masculinity and ferocity in battle did not regard the younger generation of uninitiated men as lesser men. Nor was there nostalgia for the glories of warfare and the warrior's life.

Gahuku-Gama, despite their complex ritual life, were not a dogmatically tradition-bound people. Their cultural strength lay in flexibility, curiosity, adventurousness, and openness to new things. They valued traditions so long as they were useful and served the purposes of a desir life style. When warfare ended, they d not sink into despair. Instead they simp abandoned the values, ideology, and rit als of the warrior life. Men with the tale for leadership, like Makis, with forcef personalities and political subtlety wou continue to surface as leaders, but in a ne context and with a different style.

On his return to Susuroka, Read w not unhappy to find that the harsher a more strident aspects of Gahuku life th he had known in 1950 had passed awa Nevertheless, he could not view its r placement—a ragtag attempt to emula Western life style—with much enthu asm. The Gahuku-Gama were assimila ing uncritically many of what Read r garded as the most vulgar superficialiti of Western life. Something valuable abo the unity and family closeness of the c village life was lost. With most of t youngsters off at school all week, a many of the young men away working labor contracts or in town looking f work, the organic life of the village h been channeled to other locations and pu suits. Traditional celebrations were nc replaced by village-sponsored disco-dan ing parties, and people were exchangi cartons of beer as frequently as they h

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ce exchanged pigs. Drunkenness and oholism were becoming increasing oblems in the towns and sometimes even the village level, as was a rising rate of oan-style crime.

The Gahuku were trading their cultural ity, richness, and originality for the coutrements of Western civilization: ey were joining the mainstream. The ore they tried to emulate Western life le, the more Read felt alienated from em. This was in part disappointed ro-anticism, but it was also that, like a ahuku elder knowledgeable in the val-s and wisdom of the traditional society, found himself bypassed by a younger neration bent on new horizons for which knowledge is deemed to be irrelevant.

Perhaps Read is overly pessimistic. ill not the same qualities of adventur-sness and flexibility that enabled the ahuku to discard most of their tradi-nal ideology enable them to pass rela-ely unscathed through the worst of bor-wed Western culture to a new synthesis their own beyond it? Read is not so sure.

nother dimension of Western influence s been the vigorous evangelization of e people with fundamentalist Christian-. Many Gahuku have taken to it with as uch enthusiasm (and opportunism) as they have to drinking beer. Read suggests that this new faith is the most dangerous gift of all. He fears this, not so much because fundamentalist Christianity can be a bleak, intolerant and repressive faith, but because it professes to have a monopoly on the truth. This narrowing of the field of vision could easily result in suppressing the very creativity and openness that have been the Gahuku's most important assets. The result will turn ultimately on whether Gahuku continue to feel the Christian faith is relevant to the pursuit of their basic life opportunities. If fundamentalist Christianity does not serve them, they could well abandon it, as they did the *nama* cult thirty years ago, and try something else.

In the end, however, the greatest source of distance for Read was the death of his old friend Makis. Read's debt as an anthropologist to this friendship was incalculable. Despite the warmth and support of the family upon his return to Susuroka, one of Read's major moorings in Gahuku culture had been cut loose. He no longer felt the intimate resonance with the Gahuku that his friendship with Makis had provided. Read came to realize that he had returned to the high valley not just for research and to reconnect with old friends, but also to make his peace with the place and what it had meant to him in his life. In a moving passage at the conclusion, Read describes the farewell dinner Makis's son and daughter had prepared for him in the houseyard near his old friend's grave. "As the song ended, Lucy [Makis's daughter] and some other women . . . went to the dracaena hedge surrounding his tomb. They shook the leaves of the shrubs and cried: 'Makis, you hear! Your belly can be good now. We are all together.'

"I excused myself early . . . going to bed in the darkness. I lay there, feeling it was over now. I had been released . . . .I had kept the hope that someday I would be able to make my own pilgrimage to the grave of Makis; and it was there, not many feet from my bed. And the house was quiet. He wasn't disturbing it. His family and some people . . . were drinking beer and laughing together not many feet from where both of us lay. I had come full circle, back to the beginning."

E.L. Schieffelin is an adjunct associate professor of anthropology at the University of Pennsylvania and a senior research fellow at the Institute for the Study of Human Issues in Philadelphia.

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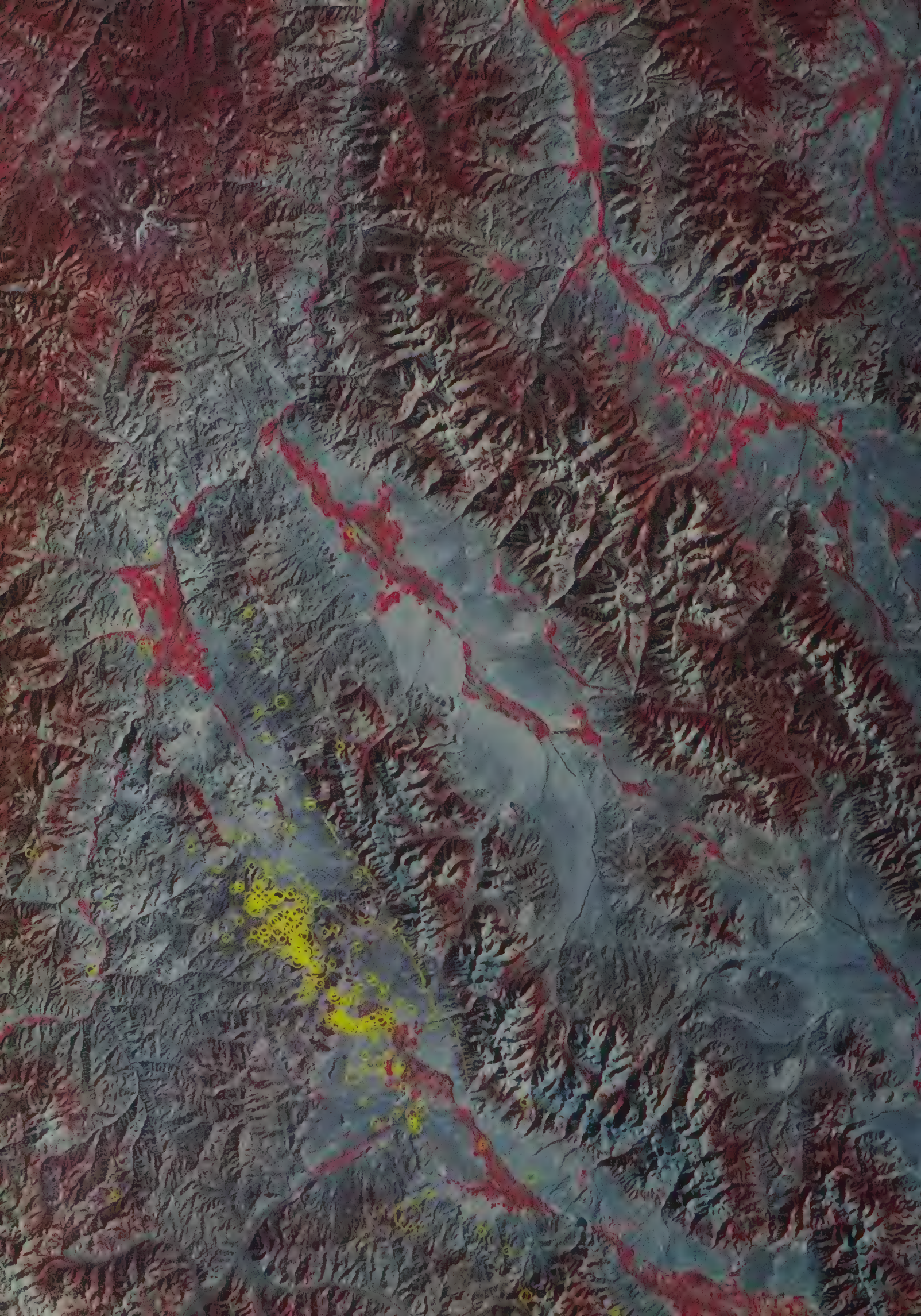


ıe yellow line in this Landsat *satellite image indicates the rupture along the Lost ver fault during the 1983 earthquake. The large yellow circle near the bottom :ates the main shock. Smaller circles represent aftershocks in proportion to their ıgnitude. The yellow square north of the fault is the town of Challis.*

Pechman/NASA

Quake Replay in the Great Basin

he continent was caught in the act of pulling itself apart the 1983 Borah Peak earthquake. When will the next one hit?

y Ross S. Stein and Robert C. Bucknam

Just after breakfast on October 28, 983, the floor of Thousand Springs Valy in Idaho started to vibrate. Within conds, the motion grew violent. In the nter of the valley, the Clark house shook hard that no one in the family could and up long enough to get out. The Lost iver fault, a seam in the earth's crust at had held for 10,000 years, was beginng to unstitch. Ten miles beneath the lley, a small patch of the fault sheared nd ruptured, and the faces of rock slid ast each other. The rupture sped northard along the fault; in three or four secnds it accelerated to a velocity of 5,000 iles per hour. The growing tear genered bundles of seismic waves as it repeatdly hit and burst through more strongly ound patches of rock on the fault. Fifteen conds after the rupture began, the faces the fault stopped moving; the rupture as now twenty-five miles long and ten iles deep.

At ground level, the rupture had etched notch along the fan of gravel eroded om Borah Peak, Idaho's highest point, amed for William E. Borah, 1865–1940, ho served for thirty-three years in the .S. Senate). Although the fault rupture ad stopped growing, the seismic waves it roduced continued to spread and colesce, like the expanding ripples formed y a stone skipped across a lake. Ten secnds later the waves passed through the wn of Challis twenty miles to the north, illing Travis Franck and Tara Leaton, ho were on their way to school when an ld masonry storefront collapsed on them. wo minutes after the earthquake began, was felt in Salt Lake City, Utah; after ur minutes, the seismic waves gently ocked Portland, Oregon; Seattle, Washngton; and western Canada, 500 miles from Thousand Springs Valley. In the next few hours, seismometers recorded the waves as they encircled the globe, yielding a magnitude of 7 on the Richter scale for the shock. The energy released was thirty times greater than that of the 1979 eruption of Mount St. Helens in Washington State. In addition to the loss of the children, the shock caused $15 million in property damage. But it also provided a rare chance to witness and investigate the repeat of an earthquake yielding to the tug of the slowly disintegrating North American continent.

Elk hunters Don Hendrickson and John Turner were driving their Ford Bronco down a dirt road in Arentson Gulch, at the northern end of the Lost River fault in Idaho, when Don suddenly felt lightheaded. "I lost my equilibrium. I felt like I was going to pass out. I was ready to tell John at that time, 'There's something wrong with me,' and right after that the Bronco just started shaking like crazy. It was off the ground completely, just rocking like this, and right soon after that, the bank dropped and I was hanging on to the steering wheel." The fault cut the ground sixty feet in front of them and dropped the side bearing the Bronco three feet. "I looked over to John and he was flying in the passenger seat. He was between the two seats, trying to get up. And he said, 'What's going on?' I wasn't about to answer, because I didn't know." Later, Don recalled, "That's when the quake went into its greatest violence, and that's when the noise came in. And it was deafening, a deafening rumble." The noise may have been the sound of rock grinding along the fault face or of landslides and boulders tumbling down the steep mountain front.

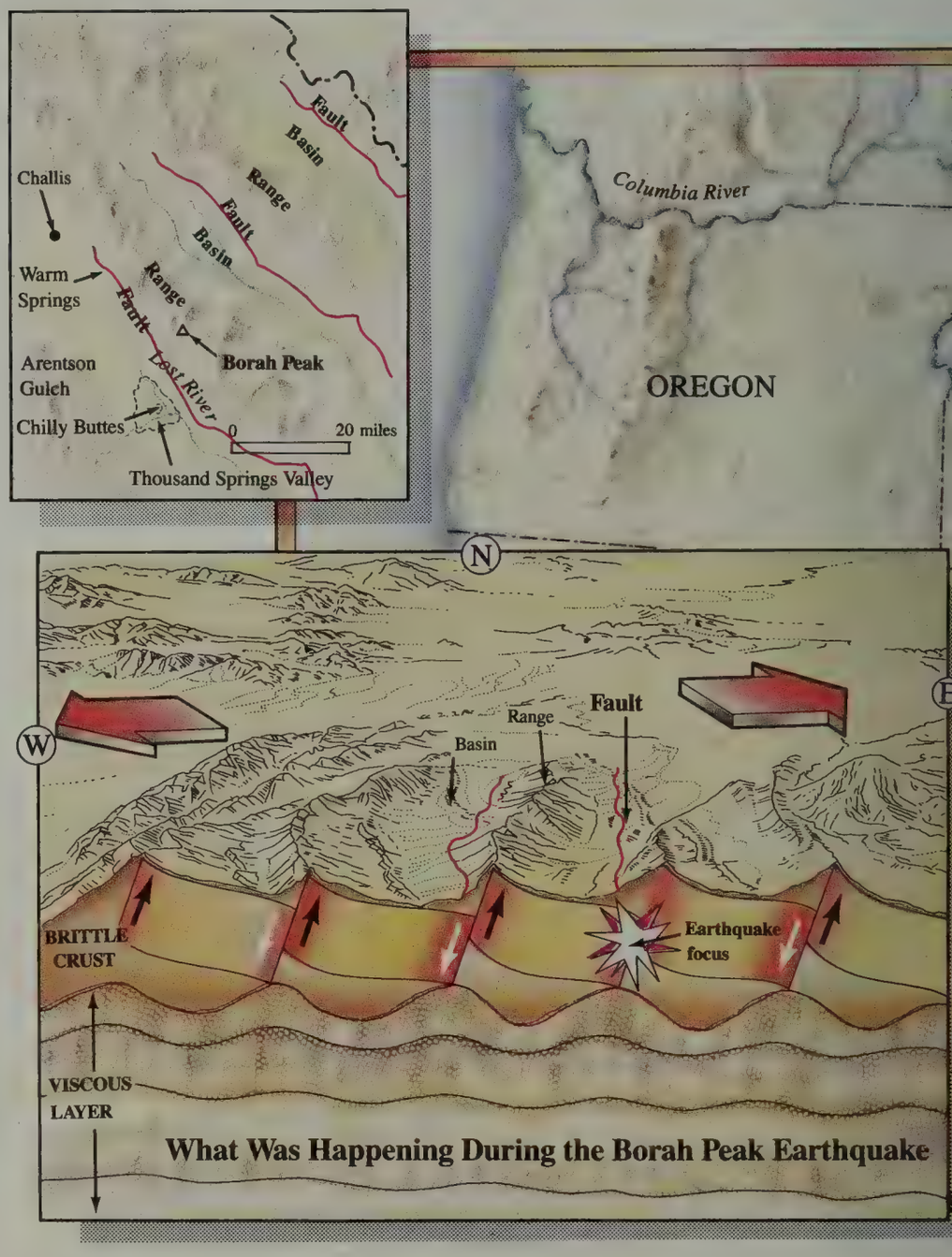
A half mile to the north of the bucking Bronco, William Knox was driving elk over a ridge while his wife, Lawana, waited below for a clear shot. When the shaking started, William felt sick and instantly went down on one knee. As the motion intensified, he lay on his stomach and was rolled back and forth by the ground motion. The shaking "might have been a half minute but it felt like a lifetime," said Lawana, who suffered whiplash from the quake's strong motion. When the shaking subsided, she watched the rupture cut across the mile-wide hillside, "just as though one took a paintbrush and painted a line along the hill." In a second it raised one side of the hill and dropped the other side three feet. Eyewitness accounts of the fault rupture—as opposed to the shaking—are rare; these observations help clarify the speed and character of the rupture.

The earthquake triggered an upsurge of ground water, the largest deluge ever recorded following an earthquake in the United States. When the members of the Clark family finally got out of their house and into their truck to escape, they found water coming up through the road and ground and shooting ten to twenty feet into the air around them. Water cascaded down adjacent Chilly Buttes and flooded the road, barring their flight. In the fields just to the north, Del Clark saw the craters first hurl dry sand into the air, then sand and water, and finally, muddy water. In a few hours, a shallow lake had formed, and in a few days, everything froze over. A string of forty craters stretched along the ground; the largest would make an Olympic-size swimming pool. Each crater was surrounded by a blanket of sand thrown up by the force of the effusion.

The holes at Chilly Buttes pocked the

The Idaho earthquake took place along what is known as a basin and range fault. The immediate cause of the quake was the sudden release of stress along the Lost River fault where its two rocky sides had been slipping against each other in opposite directions for about five million years. During the quake, the ranges were raised about one foot. The opposing rocks were depressed to form the bottoms of basins. At the same time, for reasons not yet entirely clear, the opposite sides of the fault were being pulled apart horizontally. The best hypothesis offered for the spreading is that it is caused by the slow, horizontal flow of the viscous layer of material below the earth's crust.

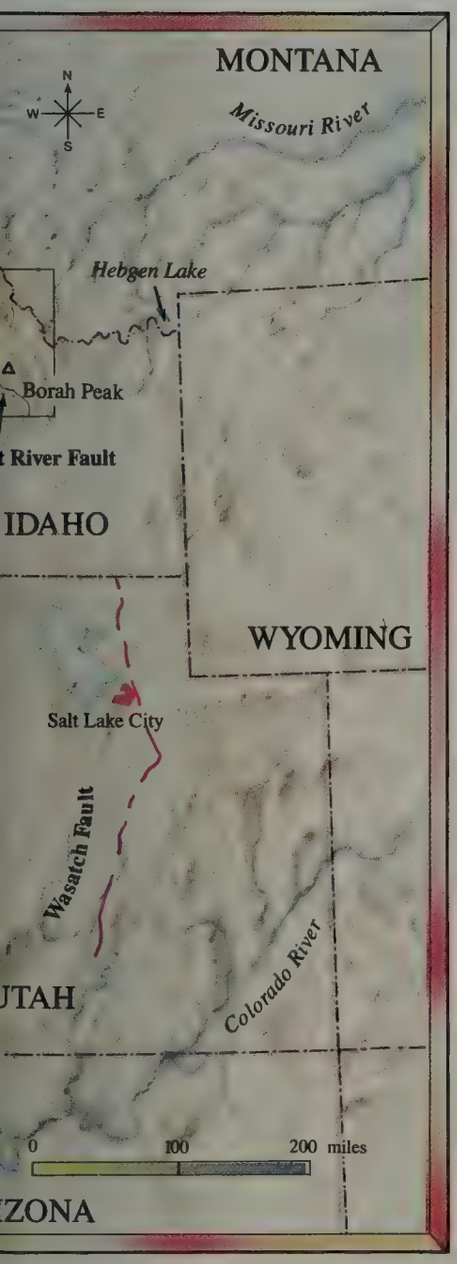
Joe LeMonnier



ground a few miles west of the earthquake rupture, suggesting that the water might have been released from the fault. But a few old-time ranchers remembered a similar fountain effect in Thousand Springs Valley after the 1959 Hebgen Lake, Montana, earthquake, which struck 150 miles away—too far away to be the result of water released from the Hebgen Lake fault. One crater formed in the valley in 1959 had been appropriated as a refuse dump. Now, twenty-five years later, the trash was ejected back to the surface in a ring around the crater. It therefore seems more likely that the passage of the seismic waves jostled blocks in the limestone buttes and the wet sand and gravel in the valley, forcing the water rapidly to the surface. (Even the name Thousand Springs Valley suggests such leakiness.) Similar sand-circumferenced craters have been found near other faults, but the eruptive process had never before been so closely watched.

Most of the postearthquake Borah Peak effusion issued from Lost River drainages much farther from the rupture than Thousand Springs Valley. To the north, the Clayton silver mine flooded, and Will Ingram's Warm Springs fish hatchery—and the fish in it—dried up. A week later, Warm Springs gushed water at ten times its former rate of flow. Ingram abandoned fish farming and, making use of the increase in water flow to generate power, now supplies hydroelectricity to the Utah Power and Light Company. About 150 miles to the east, at Yellowstone National Park, even Old Faithful reacted to the shock, lengthening the interval between its eruptions by eight minutes. Big Lost River, which skirts Thousand Springs Valley, and five other rivers coursing the neighboring valleys abruptly doubled their flow. The discharge from these streams remained high for six months. The water released by the earthquake—400 billion gallons—could supply New York City for eight months.

In September 1883, the American geologist Grove K. Gilbert wrote an article for the *Salt Lake Tribune* that began, "There are many geologists who are very wise, but even they do not understand the forces which produce mountains. And yet it must be admitted, not only that mountains have been made, but that some mountains are still rising." One hundred years later, Borah Peak proved to be among those mountains still rising. The Lost River Range, capped by Borah Peak, was uplifted one foot during the earthquake, while Thousand Springs Valley subsided four feet. As a 28-year-old assistant with the 1871 Wheeler expedition, which was charged with surveying the land won in the Mexican War of 1846–48, Gilbe spent two years exploring the Great Basi a vast inland area between Colorado an California, whose streams, rivers, an lakes have no outlet to the sea. Gilbe recognized that the regular alternation c narrow valleys and mountains—called ba sin and range topography—had been bui by repeated earthquakes on faults tha slice through the earth's crust. As the tw sides slip past each other, the ranges ar not only lifted above the valleys, they ar



also moved apart horizontally. The Great Basin is thus stretching and, as a result, being thinned.

How can mountains rise while the earth's crust is thinned? The answer may lie beneath the faults. The earth's crust behaves like a stiff rubber layer floating on a viscous, honeylike fluid. When this sandwich is pulled from the ends, the rubber first thins and then tears, or faults. The rubber on one side of the fault springs up (the mountain) and on the other side drops down (the valley). During the long period between earthquakes, the viscous substrate flows beneath the uplifted layer, filling the void left by the upward-warping mountain. Thus the mountain is progressively tilted on end and floats on an ever-thickening viscous fluid.

During the past ten million years, the Great Basin has increased its original girth by perhaps 50 percent. Gilbert could only infer that the crust was stretching, but in the past few years, the rate of extension has been measured. The arrival of faint radio impulses emitted by distant stars called quasars are timed at receivers stationed at the periphery of the Great Basin. Over the past decade, the differences in the arrival times of the impulses have lengthened, corresponding to an increase in the distance between the receivers of one-half inch per year. These measurements accord well with the rate of Great Basin extension averaged over the past ten million years as deduced by summing the slip on the faults that span the Great Basin. This rate may appear slow, but it means that three acres of real estate are created yearly in the Great Basin.

Changes in the faulted landscape of Thousand Springs Valley reveal that a major earthquake occurred there about 10,000 years ago, as well as in 1983. This remarkable encore furnishes the best evidence that we have ever had for the repetition of a major earthquake in the Great Basin. Such a pattern would have escaped notice had the 1983 Borah Peak earthquake not been so simple and accessible an event, lending itself to scrutiny by a hundred earth scientists. The most important of their efforts was the least complex: study of the displacement of the ground surface caused by the rupture. Material eroded from a mountain is carried by streams and deposited into a gently sloping fan of debris. An earthquake rupturing a fault cuts the fan at the base of a mountain; part is uplifted with the mountain, and part drops down with the valley. The small cliff, or step, formed in the fan is called a fault scarp; the height of the scarp records the amount the fault has slipped. Over time, the scarp erodes or is buried until it can no longer be distinguished on the fan surface, a process that takes about 100,000 years in arid Idaho, Utah, and Nevada.

A decade ago, geologists recognized that the existing scarp at the foot of Borah Peak was as high and fresh as any other along the 100-mile-long Lost River fault and might therefore be the site of a future earthquake. Not only did that earthquake occur, but the new scarp created by the 1983 Borah Peak shock is identical to its predecessor; the scarp is now lifted to twice its former height.

The Lost River fault thus created two nearly identical earthquakes during the past two ruptures at Thousand Springs Valley. But are all ruptures of the fault at the valley similar to the 1983 event? Borah Peak now stands one and a half miles above the deepest deposits in the valley, although they are composed of the same rock and once stood at the same level. If each earthquake increased this separation between Borah Peak and the valley by six feet, then the Borah Peak shock must have struck 1,500 times since the birth of the fault about five million years ago. Scant evidence rarely restrains earth scientists from extending a twice-observed pattern a thousand times, particularly when the replication of the pattern is so exact.

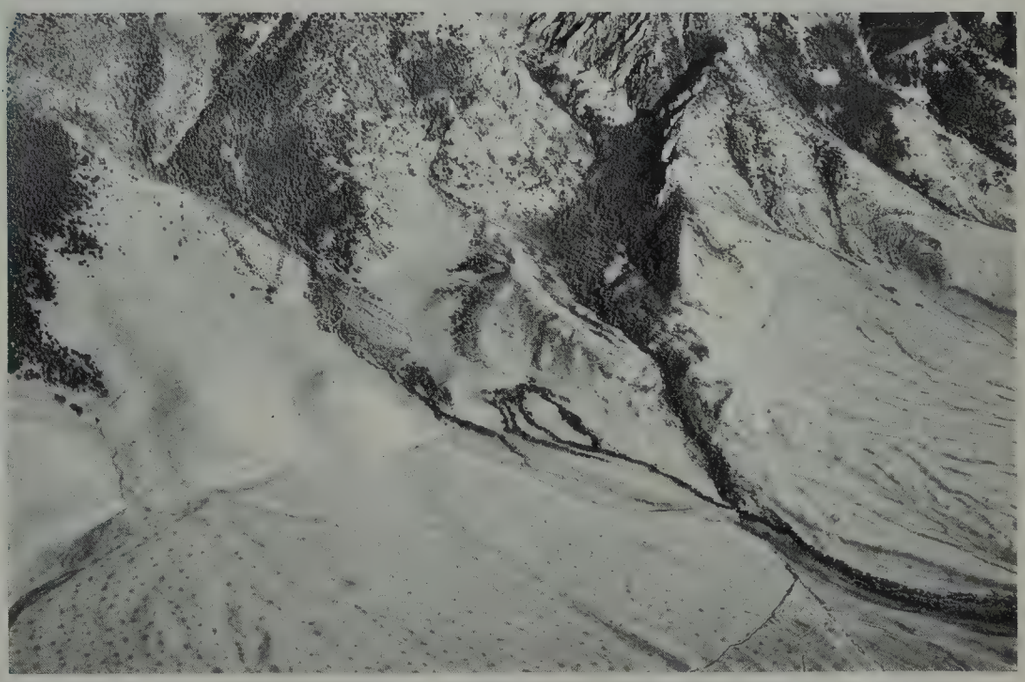
What about other strands, or segments, of the Lost River fault and strands of different faults in the Great Basin: is each fault segment repeatedly revisited by its own characteristic earthquake? Here the data stream turns into a trickle. A repeating, moderate-sized earthquake is known to occur in the center of the San Andreas fault at Parkfield, California, but the occurrence of small earthquakes is nearly random. Associating each fault segment with a particular recurrent earthquake accordingly remains a tantalizing hypothesis in need of proof. If large earthquakes do recur in the same locality, then the magnitude and location of past shocks could be used to assess future large earthquakes in the Great Basin. Because the historical record is so brief, however, the archive of large earthquakes must be read from such landforms as fault scarps.

Two sound hypotheses of earthquake recurrence lead to diametrically opposing

U.S. Bureau of Land Management

Aerial photographs taken twenty years apart show the same location of the Lost River fault. In the photograph at left, taken after the 1983 earthquake, new scarps coincide with preexisting fault scarps created 10,000 years ago. In the picture below, made in 1963, the prehistoric scarps had been subject to degradation and weathering for thousands of years and were consequently smoother, softer, and more rounded than the new scarps.

Austin Post



interpretations of what scarps bode for the future. In the first view, fault segments that lack scarps are deemed overdue for an earthquake and should be the next to go. If the rate of slip is uniform along the length of a fault, then the segments that have not yet ruptured must carry more of the load. Consider a piece of paper with a perforated line down the center and a small portion of the segments left uncut (and thus without fault scarps). When the two halves of the paper are pulled apart, the remaining segments will soon rip.

In the second view, the fault segments with the highest scarps are hosts to the greatest number of earthquakes. If the slip rate on the fault is greater at the center and diminishes to zero at the ends, earthquakes would occur more frequently in the center. Consider a piece of paper cut most of the way through; when the two sides are pulled gently apart, the center of the cut will separate the most (and thus produce the highest scarps). Along the best-studied faults in the Great Basin, the highest and freshest scarps are found along those segments near the center of the faults. Degradation of the scarp indicates that the most recent event on the Lost River fault occurred about 4,000 years ago just south of the 1983 rupture, whereas the ends of the fault have not ruptured for about 30,000 years. Thus, the evidence from Borah Peak lends new weight to the second view, suggesting that efforts to monitor faults in the Great Basin should be focused primarily, but not exclusively, on segments with the most imposing scarps and the fastest rates of fault displacement.

Observations of scarp height and freshness may therefore be plausibly transformed into forecasts of the location and magnitude of future earthquakes. Faults with prominent scarps are candidates for eventual repeat earthquakes. Both the Lost River fault in Idaho and the Wasatch fault in Utah separate into a string of twenty-mile-long fractures, each with a scarp produced by a separate prehistoric earthquake. The amount of fault slip can be gauged by the height of the prehistoric scarps, and the rupture length can be estimated by identifying scarps that extend continuously between bends or breaks in the fault. Earthquake magnitude is related to the area of the rupture multiplied by the amount of slip on the fault. Because seismometers have recorded the larger shocks in the Great Basin originating at a depth of ten miles, only the fault length is needed to estimate the rupture area. Such a forecast is a major advance in attempts to lessen earthquake hazards, but it falls

George Brogan

Following the Borah Peak earthquake, some ground on the Lost River fault shattered, below. Faults themselves do not commonly open up, but if they do, the result may be a dramatic crevice that never closes. The Wasatch fault in Utah, right, is the dark line running horizontally at the base of the mountains. The segment of the fault shown here, which last ruptured 1,000 years ago, is just south of Salt Lake City and goes through what is now a populated area. Based on the information they acquired at Borah Peak, geologists believe this part of the Wasatch fault is likely to experience a damaging earthquake sometime within the next several hundred years.

David Stoecklein

short of an earthquake prediction because the time lapse until the impending shock on each segment is missing.

Earthquake prediction is nowhere more difficult, and in few places more important, than in the Great Basin. Almost 90 percent of Utah's population lives within view of the scarps of the 230-mile-long Wasatch fault. Despite a search of newspapers and diaries kept by settlers, no large shocks seem to have been reported there since Brigham Young's arrival in 1847. Nor is an earthquake warning by monitoring for small foreshocks likely; none were detected near the eventual 1983 rupture at Borah Peak during two decades of monitoring before the main shock. Both the Lost River and Wasatch faults have been largely free of small shocks during the past twenty-five years of observation. Because it takes hundreds of years to strain the earth's crust enough to cause a segment of the Wasatch fault to rupture, the 140-year quiet does not mean that large earthquakes will not strike in the future. "Any locality on the fault line of a large mountain range, which has been exempt from earthquakes for a long time, is by so much nearer to the date of recurrence," said Gilbert in the nineteenth century. "It is useless to ask when this disaster will occur. Our occupation of the country has been too brief for us to learn how fast the Wasatch grows: and indeed, it is only by such disasters that we can learn."

In the century since Gilbert opened our eyes to the rich prehistoric record preserved in the faulted landscape of the Great Basin, the scarps have taught us something of "how fast the Wasatch grows." A decade of geologic investigation at the Wasatch fault shows that it is slipping an inch every twenty-five years, and one of its six to eight strands ruptures every 450 years. The segments of the Wasatch that appear most primed to rupture are those near Salt Lake City and Provo, Utah. With this insight, it is now incumbent upon us to ask "when this disaster will occur." Today, we can only say that the next rupture is less than five hundred years off. We will continue to sift through observations of the spectacular and tragic Borah Peak, Idaho, earthquake to see what clues might have alerted us to the imminent event. But if we cannot yet predict when the next earthquake will occur, at least we know where it will strike and how strong it will be. It is therefore vital that we prepare for it now. And we must prepare not just for the fault rupture and for the ground shaking it generates but also for the possibility of a flood of water issuing from the ground. □

male túngara frog, his vocal sac inflated, calls to females in a Panamanian pond.
chael J. Ryan

The Panamanian Love Call

What awaits the calling male túngara frog—sexual rendezvous or sudden death?

by Michael J. Ryan

Every spring, many parts of the United States explode into a cacophony of whistles, groans, burps, and shrieks. These sounds indicate that the local frog fauna has established residence in nearby ponds, and that males are advertising their readiness for their yearly sexual rendezvous. Thus the call of these animals is sexual in nature, and is produced, for the most part, by males to attract females and to ward off other males that might have stealing a mate in mind. Since the biological significance of this calling behavior is seemingly straightforward, there should be little difficulty in understanding its evolutionary history. On the contrary, my research into the communication behavior of a neotropical frog, the túngara frog, has shown that while the many compromises and contingencies that shape the evolution of this behavior are far from obvious, these factors can be documented, thereby leading to a better understanding of the evolution of behavior.

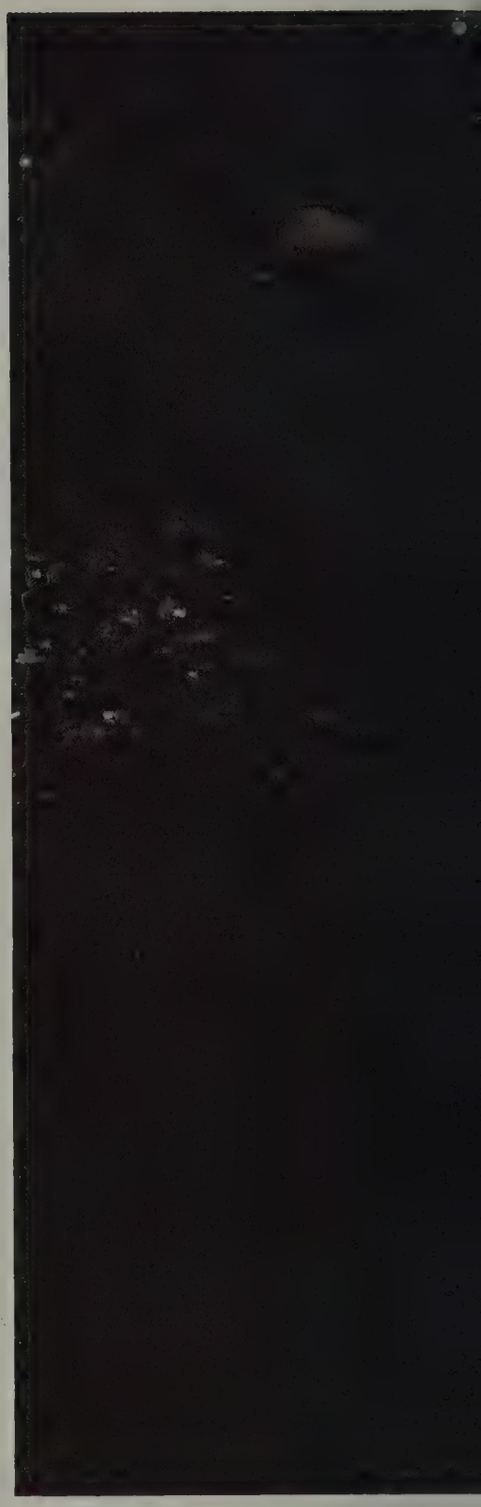
The animal kingdom is resplendent with various morphological, physiological, and behavioral traits that enhance an animal's ability to survive. The widespread occurrence of these traits, or adaptations, together with observations of the resemblance between parents and offspring, was what led Darwin to formulate his theory of natural selection. How then did Darwin explain the collection of elaborate and sometime bizarre traits associated with animal courtship, such as frog calls, that hardly enhance survival and may even promote an early death? Darwin believed the evolution of these traits occurred under the influence of sexual selection. He proposed that if a characteristic enhances an individual's (usually a male's) ability to gain access to a mate, even at some cost to survival, it should occur more frequently in the population through evolutionary time. An intriguing proposition since selection is normally thought of as a force that results in the evolution of traits that enhance survival, not traits that are maladaptive for survival.

One characteristic of frog calls, well documented during the past three decades, is the species specificity of the mating call: females prefer the calls of their own species to the calls of other species. Studies of the neurobiology of frogs and toads have also shown that the frog's auditory system is "tuned" so that it detects the conspecific mating call better than other types of sounds. The advantage of the female's discriminating behavior is obvious—mating with males from other species usually does not result in viable offspring. A female making this kind of mistake is wasting her reproductive investment, and thus we expect strong selection for female attraction to the conspecific call.

During a study of bullfrog mating behavior, however, I noticed that calls differed among males. I became intrigued by the possibility that this variation was not meaningless noise contained within the species-specific vocalization but, in fact, might influence the female's choice of a mate. It was this question that brought me to the Smithsonian Tropical Research Institute in 1978 to study the mating and communication behavior of the túngara frog on Barro Colorado Island, in the middle of the Panama Canal. This study encompassed almost three years of field research between 1978 and 1981.

Túngara frogs (*Physalaemus pustulosus*) are small, a little more than one inch in body length, and weigh less than one and one-half grams. They are fairly nondescript brown frogs that are common throughout much of Central America. In Panama they breed during the rainy season, which extends approximately from April to December. Among frogs, those with long breeding seasons are characterized by mating systems in which males typically remain stationary and vocally advertise their presence to females. Túngara frogs are no exception. These frogs breed in stagnant pools of water that range in size from the hoofprint of a tapir to a large flooded field. Much of my investigation was conducted in a small cement pool, constructed in the mid-1960s by A. Stanley Rand, a research scientist at the Smithsonian Tropical Research Institute, for his earlier studies of túngara frogs. The frogs have been breeding there naturally ever since.

Males arrive at the breeding site around dusk and immediately begin to call, some producing more than 7,000 calls in a single night. The males are almost evenly spaced around the perimeter of the pool, and any male intruding on a calling male's personal space is threatened by aggressive, mewlike calls. If the intruder is not discouraged, a wrestling bout often ensues. Although physical combat is not frequent, on several occasions it resulted in the death of one of the participants. As with many frogs, females come to the breeding site only on the nights they mate. When a female arrives she spends a fair amount of time, sometimes hours, swimming among the chorusing frogs and sitting stationary in front of calling males. One female sat in the corner of the breeding site in front of a calling male for approximately twenty minutes, swam away to position herself in front of another call-



Less than one and one-half grams in weight and a little more than one inch long, a túngara frog perches comfortably on the head of a giant toad, Bufo marinus.

Merlin D. Tuttle; Bat Conservation International

ing male about three feet away for the same length of time, and eventually returned to her original position where mating took place. Males do not attempt to mate with the female during these sojourns. Instead, mating is initiated when the female makes physical contact with a calling male, the male then clasping the female from the top.

An analysis of 751 matings by 617 measured and tagged individuals revealed that larger males were more likely to mate. The pair remain clasped, or in amplexus, until the calling subsides, usually about midnight. Often they leave the water and wait on the shore until this time. Sometime after midnight, the pair return to the water, settle on a site, and construct their foam nest; this site usually bears no relationship to the place from which the male was calling.

Nest construction is an arduous task. The female passes her eggs, a few at a time, from her cloaca. The male grasps them with his hind legs, moves them past his cloaca where fertilization takes place, and, in a quick, beating motion, fluffs the jelly matrix surrounding the eggs into a foam, much the way we beat egg white into a meringue. Nest construction takes about an hour, and the male is visibly tired toward the end. Both frogs then abandon their future offspring, which will hatch into tadpoles in a few days. If they are lucky enough to avoid the dragonfly nymphs and other voracious predators inhabiting the pools, the tadpoles will metamorphose into small frogs in about six weeks time.

Females appear to choose larger males as mates, and I wanted to know how they do this. Since males have little of value to offer the females besides themselves—they do not defend any resource of potential use, such as a nesting site—some aspect of the male's characteristics must be important. And since the males put so much time into calling, that seemed a likely place to start. The complex call of the túngara frog consists of two components: one whine and from zero to six chucks (much of this complexity was deciphered by Stanley Rand in the 1960s). The whine is almost half a second long and resembles the sounds emanating from a Star Wars video game. The chuck is of much shorter duration and sounds like an abbreviated burp. Males always produce a whine and females are attracted to a loudspeaker broadcasting only the whine. Chucks never occur by themselves in nature, but if dissected from a call and broadcast to frogs, they do not elicit a response from either sex. The whine, then, appears to be necessary and sufficient for species recognition. Is the chuck, perhaps, a meaningless frill? Not quite. When a male is part of a chorus he usually produces chucks, and larger choruses are characterized by more chucks. Males also add chucks to their calls as a female approaches. In one case, a male increased the number of chucks in his call from two to six in a matter of seconds—the largest number of chucks I recorded.

These observations suggested that the social milieu of the animal influences the complexity of its call. Rand demonstrated this by presenting a male with calls of varying complexity. As the broadcast call increased in number of chucks, so did the male's response. The reason males add chucks is also clear: when presented with two calls, one without chucks and one with chucks, females preferred the latter.

But these results presented a paradox. If males were at the breeding site to attract females, why didn't they always produce calls that females found most attractive? The benefit of such a behavior is evident—a greater chance of mating. Perhaps there is a cost to producing chucks. One obvious cost is energy. Although at the time of my study no one had ever measured the amount of energy used by a vertebrate in sexual display, many studies had assumed that the cost was significant. Together with Terri Bucher and George Bartholomew of the University of California, Los Angeles, I investigated the energetic costs associated with calling. We did this by placing a male in a small respirometer. To stimulate the frog to call, a speaker broadcasting calls was placed outside the respirometer, and a microphone recorded the number of calls produced. After about thirty minutes of calling, we measured the amount of oxygen that was depleted in the respirometer and fou that calling was a very expensive ventu for the male. Metabolic rate increas about 500 percent above what it was wh the frog was at rest. However, no mo energy was used to produce calls wi chucks than calls without chucks. S while there is a substantial cost to callin there is no increase in cost for maki those calls more attractive.

In the 1950s, Peter Marler, now at T Rockefeller University, suggested th some calls of distantly related bird speci have evolved similar structures becau they serve similar functions. Alarm ca warn others of the presence of a predat without revealing the warner's locatio Mobbing calls elicit assistance from ot ers by revealing the signaler's locatio

Thus alarm calls should be ventriloquial, while mobbing calls should be easy to locate. These calls each share a similar structure. But the alarm call is also amazingly similar to that of the whine, while the mobbing call resembles the chuck. Rand suggested that just as predation had molded the structure of these calls in birds, it played a similar role in the call of the túngara frog. At the time he made this suggestion, however, there were no known predators of frogs that used the frog's call for locational cues.

That changed quickly when Merlin Tuttle of the Milwaukee Public Museum netted a bat with a frog in its mouth on Barro Colorado Island. Tuttle suggested that this bat (*Trachops cirrhosus*), which has become popularly known as the frog-eating bat, not only eats frogs regularly but locates them by homing in on their mating calls. Tuttle returned to Barro Colorado Island in 1980 to begin studies of bat–frog interactions. We then teamed up to investigate the possibility that the bats homed in on the call of the túngara frog and, especially, the possibility that they preferred calls with chucks.

Frog-eating bats eat túngara frogs more than they eat any other species of frog. At one pond, Tuttle, our assistant Cindy Taft, and I observed ninety-five instances of predation during fourteen and one-half hours of observation—6.6 frogs eaten per hour. We captured some of these bats, placed them in a large flight cage, and found that they were readily attracted to túngara frog calls that were broadcast from speakers. Echolocation signals and vision played no role—the bats were attracted to the calls alone—a behavior then thought unusual. Subsequent studies, however, especially ours of the African bat *Cardioderma cor,* demonstrated that a variety of bats use prey-generated cues while hunting. In the flight cage, we presented bats with a choice between calls without chucks and calls with chucks. Of the five bats tested, all were more likely to fly to the speaker producing the calls with chucks. We also tested this hypothesis in the field. Placing two small tape recorders in areas that we knew the bats frequented, and using a night-vision scope, we counted the number of passes the bats made over the recorders broadcasting each call type. Again, there was an overwhelming prefer-

ence for calls with chucks. These results demonstrate the predicament faced by males trying to attract mates. They can increase their attractiveness to females at the cost of a higher predation risk or they can play it safe but take the chance of not being selected as a mate. The variable complexity of the mating call in these frogs seems to have evolved to allow males to strike a compromise between the benefits of attracting a mate and the costs of attracting a predator.

If the calling of a single male will attract a predator, what about the cacophony of an entire chorus, which can consist of more than 400 males vocalizing their sexual intent? Would more calling males attract more bats? And how does chorus size influence a male's ability to attract a mate? Is he less likely to succeed when he is one of many attempting to attract a female's attention? These questions led us to quantify the costs and benefits of chorusing behavior for this species of frog. We monitored predation rate and mating success at a single pond where chorus size fluctuated each night, and found that it was advantageous for male frogs interested in both mating and surviving to join larger choruses. The number of frogs eaten by bats did not increase with chorus size; therefore, the actual risk of predation for any individual frog was lower in larger choruses. The larger choruses appear to offer some predator protection, probably through safety in numbers. A male's mating success also does not suffer when he is a member of a larger aggregation of calling males. On average, males are mo likely to mate when part of a larger chor because proportionately more females a present at larger choruses. Why this is so not clear.

But just what is it about a male, besid his complex calls, that makes him mo attractive to females? Since larger mal are more likely to be chosen by females, asked what characteristics of the ma would result in this type of mating prefe ence? In his study of bullfrogs (*Natur History,* April 1979), Richard Howa also showed that females preferred mate with large males and that these lar males defended higher-quality territorie used as oviposition sites, than did small males. In his study, females could ha been assessing territory quality or son

Using a frog's mating call as a locational cue, a frog-eating bat swoops down to capture a calling male, left, and flies off with the prey in its mouth, below.

Both photographs by Merlin D. Tuttle; Bat Conservation International

ther aspect of the male's characteristics. One reason I decided to study túngara rogs is that males do not defend resources sed by females, thus the female's choice hould be influenced only by the male's haracteristics.

Given the demonstrated costs in terms f energy and predation incurred by call- ng males, the mating call is of obvious mportance in mate attraction. There was eason to believe that the call might con- ain information about male body size, nd that female choice might be based on his information. The frequency, or pitch, f a vocalization is determined largely by he mass of the vocal cords. This is true for oth frogs and humans. For example, it is he hormone-induced increase in vocal ord mass that causes the sometimes embarrassing voice change experienced by young men as they reach puberty. Biologists had long noted that in frogs there was a correlation, both among and within species, between the pitch of the mating call and the frog's body size. This is true simply because larger frogs have more massive vocal cords. When I examined the mating calls of 132 males, there was a significant correlation between body size and the pitch of the chuck. Together with the observation that females are more likely to choose larger males as mates, this suggested that females are more attracted to lower-frequency calls, and it is this preference that results in the mating success of larger males.

One of the advantages of working with frogs is the ability to test female choice through playback experiments. I used synthetic calls in order to control for variation in the whine. When I presented females with simultaneous calls containing a high-frequency chuck and a low-frequency chuck, females were attracted preferentially to the latter. I then used two calls that were closer in frequency and the females still preferred the lower-frequency call. Thus, experimental evidence supports the hypothesis that females mate with larger males because they are preferentially attracted to their calls.

These results demonstrate that there is selection, through the action of female mate choice, on the male's call. They do not demonstrate, however, that the calls have evolved in response to this selection. Evolution need not take place in response to selection. Although selection can be measured within one generation, evolution is a historical process. If generation times are long, as they are for almost all vertebrates, it is not possible to witness evolution in action. Instead, a retrospective analysis is necessary. If sexual selection has influenced the evolution of the call of túngara frogs, then these frogs should have a call frequency that is lower for their body size than that of closely related frogs, provided that sexual selection has not acted similarly in these other species. The latter assumption is probably valid. Only túngara frogs have the two-component call—thus only in this species can selection act on a component of the call that is used for intraspecific interactions without affecting the call component used for species recognition.

I compared the call of túngara frogs with the calls of twenty-nine species from the same subfamily (Leptodactylinae). First, the relationship between body size and frequency was determined for all species. This yielded a prediction of the fre-

Below: Prior to fertilization, the male clasps the female from above with his underside resting against her back. Right: Still clasping the female, the male uses his hind legs to beat the jelly matrix surrounding the eggs into a foamy nest.

Both photographs by Michael J. Ryan

quency of the call for any species given its body size. Species were then compared by determining the magnitude by which their frequency departed from that prediction. Túngara frogs have a frequency that is the lowest for its body size of all the species that were examined; in fact, it is 252 percent lower than that predicted by the body size–frequency relationship for the subfamily. If the analysis is restricted to only members of the genus *Physalaemus*, túngara frogs still have the lowest frequency call for their body size—314 percent lower than predicted. Clearly, these frogs have evolved very-low-frequency calls.

Although call frequency has decreased without a concomitant change in body size, vocal cord mass must have increased to achieve such a result. Together with George Drewry and W. Ronald Heyer of the Smithsonian Institution's National Museum of Natural History, Rand examined the vocal morphology of this species. Túngara frogs have achieved this low-frequency call by the addition of two large, pendulous masses that hang from the vocal cords, thus drastically enhancing the mass and lowering the frequency of vibration. Robert Drewes of the California Academy of Sciences and I have surveyed the vocal morphology of frogs in the species group to which túngara frogs belong. Although other members of the genus may possess additional masses associated with the vocal cords, we only find the addition of very large, pendulous masses in túngara frogs. Peacock tails and deer antlers are usually cited as examples of elaborate traits that have evolved under the influence of sexual selection. Although I am admittedly biased, these traits seem to pale in comparison with the spectacularly pendulous masses, resembling a pair of testes, that hang from the vocal cords of a male túngara frog.

The seemingly simple behavior of a male frog calling to attract a mate appears to be the result of a series of complex, interacting factors. The case of the túngara frogs demonstrates how the true evolutionary history of a behavior can only be glimpsed by a combination of approaches that consider mating behavior, energetics, predation, phylogeny, sensory physiology, and morphology. The various disciplines within biology are only artificial constructs in the pursuit of science and are not adhered to by real organisms evolving in the real world. The necessity of a broad, integrative approach is becoming clear not only in studies of behavioral evolution but within the whole field of evolutionary biology. □

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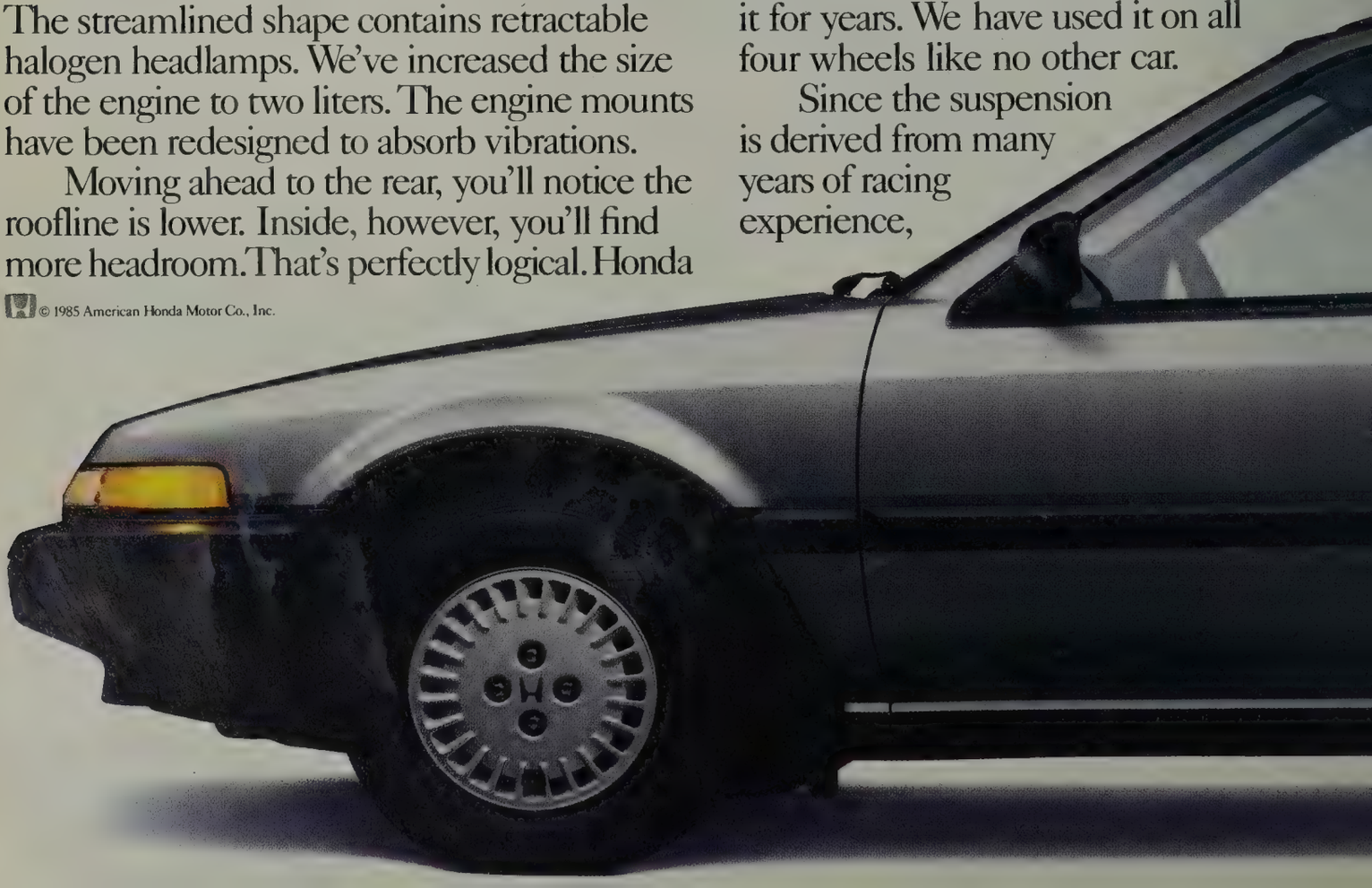

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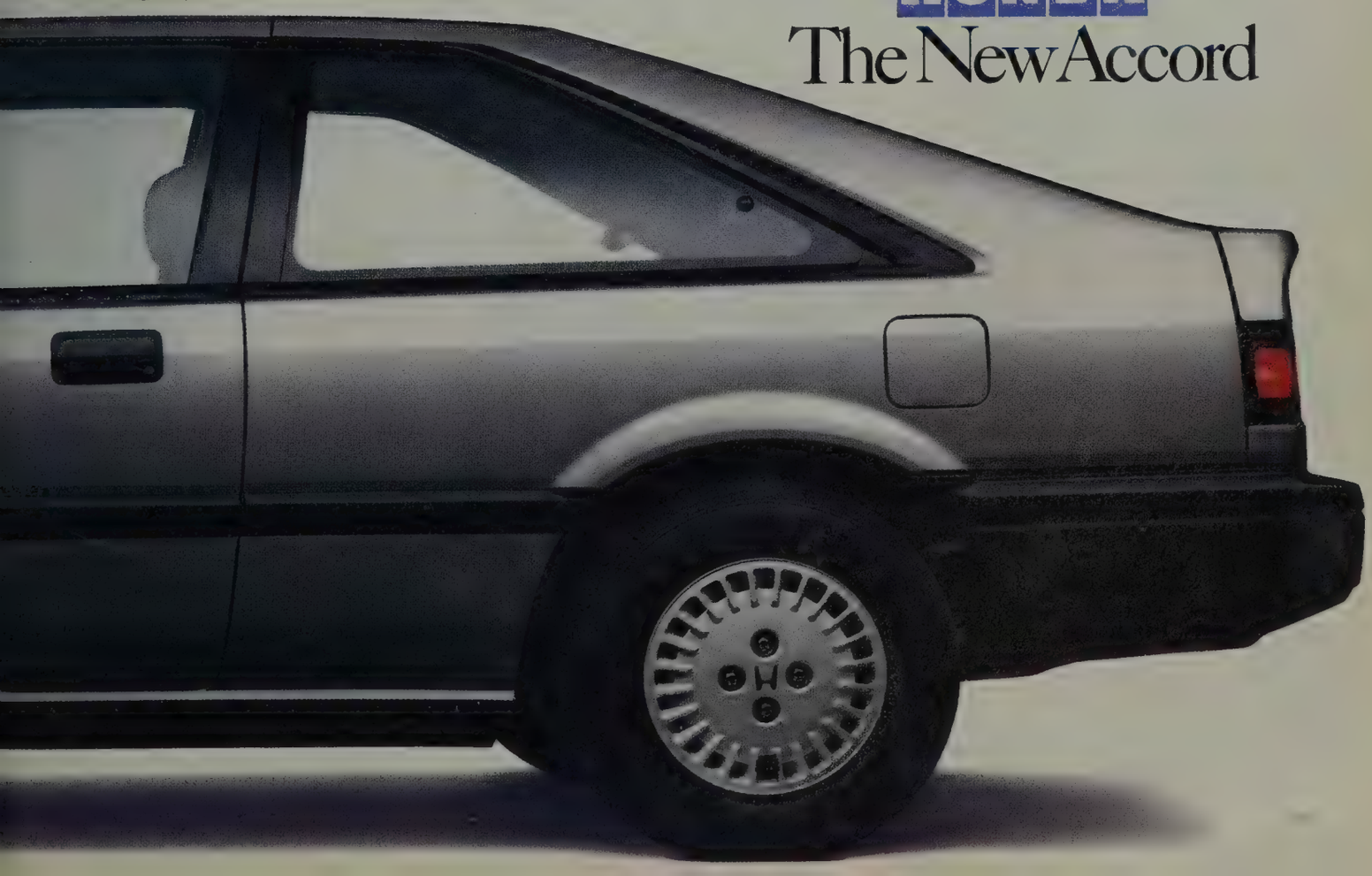

A widely distributed color lithograph, based on a late nineteenth century painting by Cassilly Adams, portrays Custer's final moments on Last Stand Hill. The Indian camp that Custer sought to attack appears in the background, on the other side of the Little Bighorn River. The saber brandished by Custer is an example of artistic license.

Courtesy of the Amon Carter Museum; Fort Worth, Texas

CUSTER'S LAST FIG
The Original Painting has been Presented to the Seventh Regiment U.S. Cavalry
BY ANHEUSER BUSCH BREWING ASSOCIATIO
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Post-mortem at the Little Bighorn

Archeologists sift for clues at Custer's fatal battleground

by Douglas D. Scott and Melissa A. Connor

The anniversary of the Battle of the Little Bighorn falls on June 26, the day 110 years ago when George Armstrong Custer led some 210 men to their death in the Montana Territory. In the years that followed, the story of Custer's Last Stand assumed legendary proportions, while much of the hard evidence of the battle remained unexamined. Then in August 1983, a wildfire scorched four-fifths of the 760 acres of Custer Battlefield National Monument (a cigarette tossed from a car on nearby State Route 212 may have ignited the drought-stricken vegetation), and the National Park Service, which administers the Monument, enlisted local archeologist Richard Fox to see whether artifacts might be recovered from the denuded landscape. The result has been a full-fledged study by the Midwest Archeological Center of the National Park Service and the University of Nebraska.

Along with Dick Harmon, of the U.S. Geological Survey, and Richard Fox, and aided by many volunteers, we have spent two field seasons encouraging the earth to yield its secrets about this historic battle. We chose to view the battleground as a crime scene, and by using forensic techniques, such as microscopic examination of firing-pin marks on cartridge cases and rifling marks on bullets, we have been able to determine the weapons used by the various participants. These techniques, combined with the standard archeological practice of recording where artifacts are found, have enabled us to deduce the movement of individual firearms over the field of battle, verify cavalry positions, and pinpoint the previously unknown placement of the Indian warriors. Many human skeletal remains were also found, and these tell us of the wounds the men received, as well as the soldiers' general health and condition at the time of death.

The story of the battle begins in 1868, when the Treaty of Fort Laramie was signed with the Sioux and Cheyenne. Among other things, the treaty granted the Black Hills area to the Sioux for "as long as the grass was green and the sky was blue." In the early 1870s, however, rumors spread of gold in the Black Hills, and white miners began slipping into the reservation. In 1874, the U.S. government sent a geological team under Custer to check out these rumors. Gold was among the minerals found, and thereafter there was no stopping the hordes of miners who flowed onto the Indians' land.

The Sioux were disgusted with the government's inability to keep white people from trespassing, especially in the Black Hills, which they considered sacred. As the whites did not seem to be respecting the treaty, many of the Indians saw no reason to abide by its terms and stay on the reservation. Along with Cheyenne from other Indian agencies, thousands of Sioux spent the winter of 1875–76 on their traditional hunting grounds in Montana and the Dakotas, despite a government warning that unless they returned immediately, they would be considered hostile and subject to military action.

In May of 1876, a three-sided campaign was launched to shepherd the Sioux and Cheyenne back to their assigned lands. One column, under Gen. John Gibbon, marched east from Fort Ellis (near present-day Bozeman, Montana). A second column, led by Gen. Alfred Terry and including Custer, headed west from Fort Abraham Lincoln (near present-day Bismarck, North Dakota). The third column departed from Fort Fetterman (near present-day Sheridan, Wyoming) under the command of Gen. George Crook and moved north into Montana. These three units, totaling about 3,000 men, were to meet near the end of June in the vicinity of the Little Bighorn River.

Unknown to Terry and Gibbon, Crook encountered Indians near Rosebud Creek in southern Montana, was defeated by them on June 17, and withdrew his men to Wyoming. Meanwhile, Terry, with some 921 men, mostly cavalry, was moving west up the Yellowstone River to the Little Bighorn. On June 22, the cavalry, led by Custer, left Terry's command to scout ahead.

The 7th Cavalry consisted of twelve companies, each authorized to contain fifty to sixty-four men. In reality, most field units never operated at authorized strength, owing to low budget allotments from Congress, high desertion rates, and

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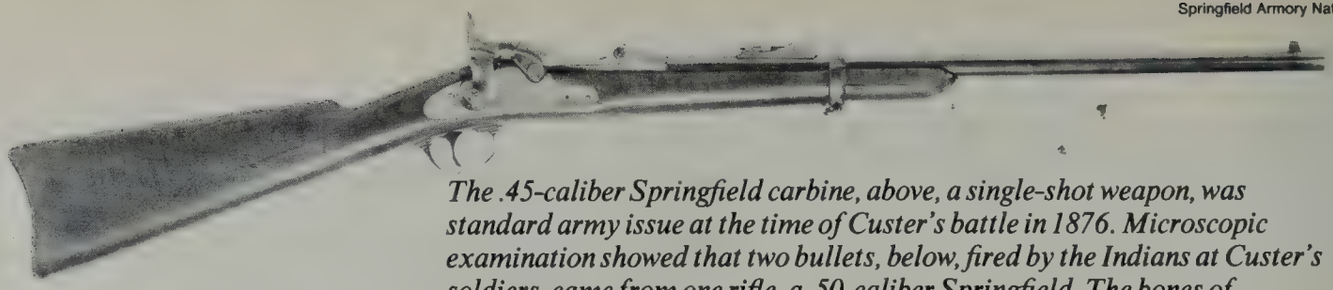


The .45-caliber Springfield carbine, above, a single-shot weapon, was standard army issue at the time of Custer's battle in 1876. Microscopic examination showed that two bullets, below, fired by the Indians at Custer's soldiers, came from one rifle, a .50-caliber Springfield. The bones of a left forearm, bottom, uncovered during the recent excavations at the battlefield, belonged to a soldier about twenty-five years old.

men on detached duty. Custer commanded about 715 men, about 160 men under authorized strength. Custer's rank was lieutenant colonel (brevet major general). A brevet rank was an honorific and temporary grade given for special service and as an award for gallantry in action. Custer's second-in-command was Maj. Marcus Reno. Next in line was Frederick Benteen, the regiment's senior captain.

Early on the morning of the 25th, the 7th Cavalry was on high ground, with Rosebud Creek behind them to the east and the Little Bighorn about sixteen and a half miles to the west. From a spot subsequently dubbed the Crow's Nest, Custer observed a large Indian camp on the far side of the Little Bighorn. Worried that the Indians might escape, Custer decided to attack and descended westward into the valley. Near the Crow's Nest, Captain Benteen was ordered to take three companies and keep to the south, to block a possible escape route. The pack train, carrying ammunition and guarded by one company, followed Benteen, while the other companies went ahead. At midday, a few miles from the Little Bighorn, Custer again divided his command, ordering Major Reno to take three companies along the river bottom and attack the Indian camp on its southern end. The remaining five companies followed Custer westward along the ridge to the north, preparing to support Reno.

About 3:00 P.M., Indian warriors engaged Reno and his men, forcing them to retreat back across the river and up the bluffs to a defensible position. Meanwhile, Custer must have realized the gravity of the situation as the north end of the Indian camp came into view. About 3:30, Custer's adjutant sent a message to Benteen: "Benteen, Come on. Big village, be quick, bring packs. P.S. Bring pacs [*sic*]. W.W. Cooke." The messenger, bugler John Martin, was the last to see Custer and the men in his five companies alive.

Summoned by the message, Benteen's forces and the pack train arrived some forty-five minutes later, joining Reno and his men on the hilltop. All were pinned down for two days, fighting to keep their defensive position and wondering when

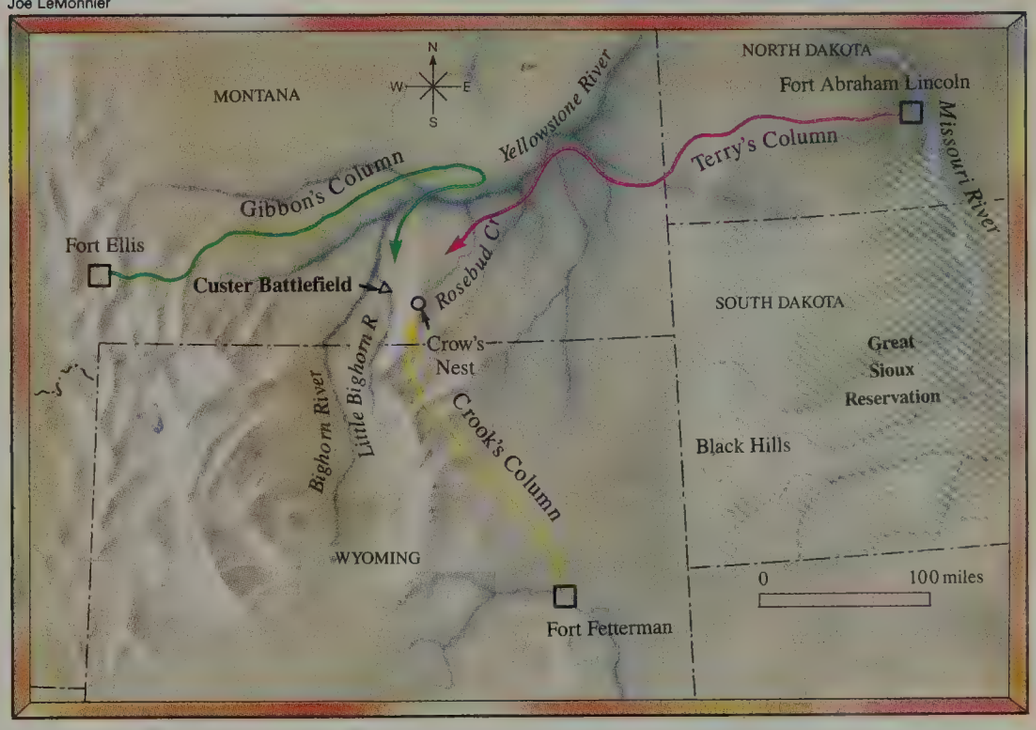
Both photographs from Midwest Archeological Center, National Park Service

Custer would relieve them. The Indians finally retreated on June 27, when General Terry arrived, joined by General Gibbon's column. Reno sent two men to meet the advancing column, and they found Terry and Gibbon near the abandoned Indian camp. Here, a scout brought the news: Custer and his men lay dead on a ridge above the Little Bighorn.

From that moment until the present, Custer's movements after the messenge left him have been the subject of hot de bate. Soon after the battle ended, hov ever, eyewitness accounts began to appea in newspapers across the country. The wi nesses were the survivors—the Indian Weary of army pursuit, the warriors ha returned to their reservations, where In dian agents interviewed them. Only the did the warriors learn for certain the ider

In May of 1876, approximately 3,000 soldiers, commanded by Generals Gibbon, Terry, and Crook, set out to round up Plains Indians who had left their reservations. The three columns were to meet near the Little Bighorn River in late June. The ill-fated 7th Cavalry, under Custer, made up the majority of Terry's command.

Joe LeMonnier



ty of the commander they had defeated.

Different versions of Indian accounts of ıe battle appeared in different papers ıd journals, and many began to question ıeir accuracy. People suspected distorted :porting by glory-seeking correspondents r faulty translations of Indian words or gns. The Indians, fearing retribution om the army, may also not have told the hole truth. As a result, the Indian ac-ounts were long scorned, although in the ast fifteen years, historians who have re-iewed them have concluded that the gist f the reports rings true.

The Indians' accounts, collected from urvivors up until the middle of this cen-ury, state that the camp on the Little Bighorn was established shortly after Crook's defeat at Rosebud Creek, and in-luded the Sioux who had fought in that onfrontation. Nevertheless, Custer's ar-ival apparently took the camp by sur-prise. As Custer and his men moved north long the ridge, a large contingent of Sioux pressed the attack from the south. A group of Cheyenne and some Sioux also ttacked the soldiers from the north and orthwest.

At first the shooting was from a dis-ance, but as the soldiers stood their ground, apparently in a V-shaped forma-ion, the intense fire thinned their ranks. It vas then that the warriors were able to nove in and essentially surround the cav-lry. Once many of the soldiers were dead or wounded, the Indians swooped in on hose that remained, finishing them off in and-to-hand combat. Accounts tell of killing wounded soldiers and of stripping he dead of their guns, ammunition, cloth-ng, and other useful items. Some warriors scalped the dead or mutilated their re-mains, as was their custom in warfare.

In an attempt to make the battleground speak for itself, during the summers of 1984 and 1985 we used the techniques of archeology to unearth thousands of arti-facts, despite events that had disturbed the area over the intervening years. After the battle, the Indians removed their dead and wounded, but the dead soldiers lay in the hot Montana sun for nearly three days. When the surviving members of the 7th Cavalry began the onerous task of burying the dead, the bodies were bloated, black-ened, and almost unrecognizable. Because there were few shovels or other tools with which to do a proper job, cups, plates, and other available implements were used to mound dirt over the bodies. Afraid that the Indians would return and attack again, the soldiers covered most of the dead with just a little soil and sagebrush.

The powdery soil was not enough to keep coyotes and other scavengers from the graves, and the action of wind, rain, and snow compounded the problem of keeping the men buried. In 1877, the army reburied the exposed bones. All the officers' remains, however, were exhumed and shipped home, except those of Lt. John Crittenden, whose father asked that he be left where he fell. Persistent reports of exposed remains brought the army back in 1879 for another reburial. Finally, in 1881, the army exhumed all the remains from the battlefield and reburied them in a mass grave on Last Stand Hill, near where Custer's body had been found. A large granite marker was placed over the grave that same year.

While the reburial teams stripped the battlefield of its most conspicuous bones and artifacts, many important clues were left to await archeological exploration. We divided our work into three parts. The first was a metal detector survey of the battlefield. Volunteers, often experts in the use of detectors, walked about five yards apart, covering the field. Where their detectors beeped, they flagged the spot. Behind them came a recovery crew that excavated cautiously, searching for the object that had caused the detector to signal, but not moving it out of place. Finally, the survey crews came along to plot each artifact's position on a grid system. This crew also recorded the depth at which the artifact lay and, in the case of bullets and cartridges, noted the orientation and the declination of the piece. Only then was the artifact collected.

The second part of the project was a search in a gully known as Deep Ravine, where twenty-eight men were said to have been buried in place and never subsequently exhumed. At first, we thought that the metal detectors would locate these men, but even after several close examinations, only a handful of scattered artifacts came to light. In 1985, C. Vance Haynes, a geomorphologist from the University of Arizona, volunteered to examine the ravine. Haynes found a deeply buried area that conforms to the historic descriptions of the burial locale; we hope to excavate it in a future field season.

In the third part of our work, we exca-

As he approached the Little Bighorn, Custer divided up the twelve companies under his command. While Captain Benteen trailed behind with four companies and a pack train, Custer ordered Major Reno to take three companies and attack the Indian camp from the south. Custer himself led the remaining five companies farther north. Reno and his men were driven back to a defensive position, where they were eventually joined by Benteen's forces. The detail map shows the battlefield where Custer deployed his men. One company, under Lieutenant Calhoun, was arranged in an arc, facing south. Another company, under Captain Keogh, was positioned farther north. Custer's other three companies stretched in a line from Deep Ravine to Last Stand Hill, confronting Indians attacking from the north and west.

Joe LeMonnier; Detail Map after Midwest Archeological Center, National Park Service

Archeological Finds at Custer Battlefield National Monument

vated the immediate areas around marble markers that had been placed to commemorate the locations where Custer's men fell. Set in place fourteen years after the battle and more than nine years after the bodies were disinterred and placed in a mass grave, these marble markers replaced wooden ones, many of which had fallen down or been burned by wildfire. Two hundred fifty-one markers dot the main battlefield, yet only about 210 men fell with Custer. One reason to excavate around the markers was to test the appropriateness of their locations.

These three activities—the metal detector survey, the search in Deep Ravine, and the excavations near the markers—uncovered about 2,200 artifacts, 300 human bones, and 200 bones of horses and other animals. Additional materials (still being analyzed) were collected in 1985 a the Reno-Benteen defense site.

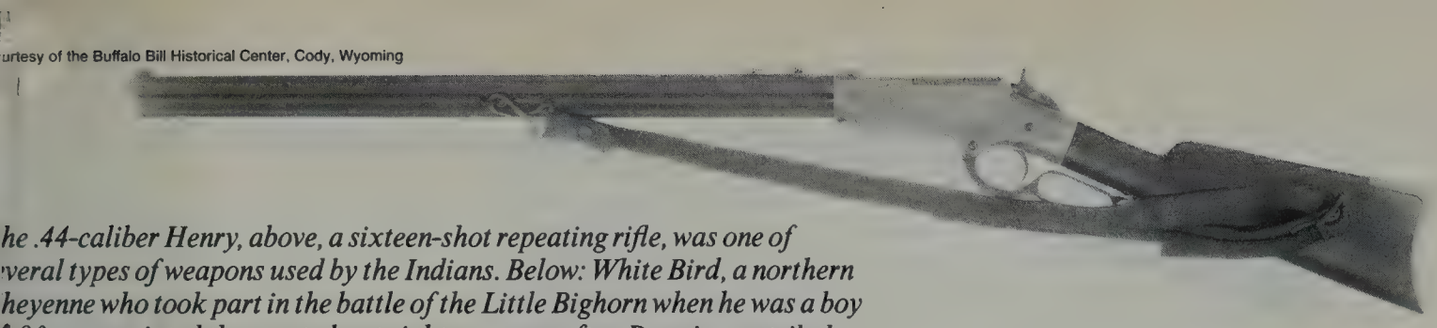
The metal detector survey located hu dreds of bullets and cartridge casings. I most cases we could assume that spe cartridges from Springfield carbines an Colt revolvers—the regulation cavalr weapons—had fallen in cavalry position and that bullets from these guns had bee fired toward the Indians. Conversely, w assumed that bullets found in associatio with cavalry remains and artifacts can from Indian fire, and that cartridges of th corresponding calibers indicated the I dian positions.

Even before the analyses were com plete, we knew that the Indians we much better armed than had been prev ously documented. The subsequent fir arms analyses have identified twenty-fiv different types of guns used by the wa riors. Metal arrowheads were also foun showing that the stereotypical bow an arrow was also used.

Indian arms included army issu Springfield carbines and Colt revolver These could have been captured either the Rosebud skirmish with Gener Crook's forces or in the valley figh against Reno; some were no doubt take from Custer's men. Antiquated muzzl loading firearms were also well repr sented. Other Indian arms included th .44-caliber Henry, the .44-caliber Mod 1866 Winchester, and the .44-calib Model 1873 Winchester, all repeating r fles. The army did not issue repeating r fles in 1876. The army's single-sh Springfield was not as fast as the repea ing rifles, although it was more powerf and more accurate than the majority the Indian arms.

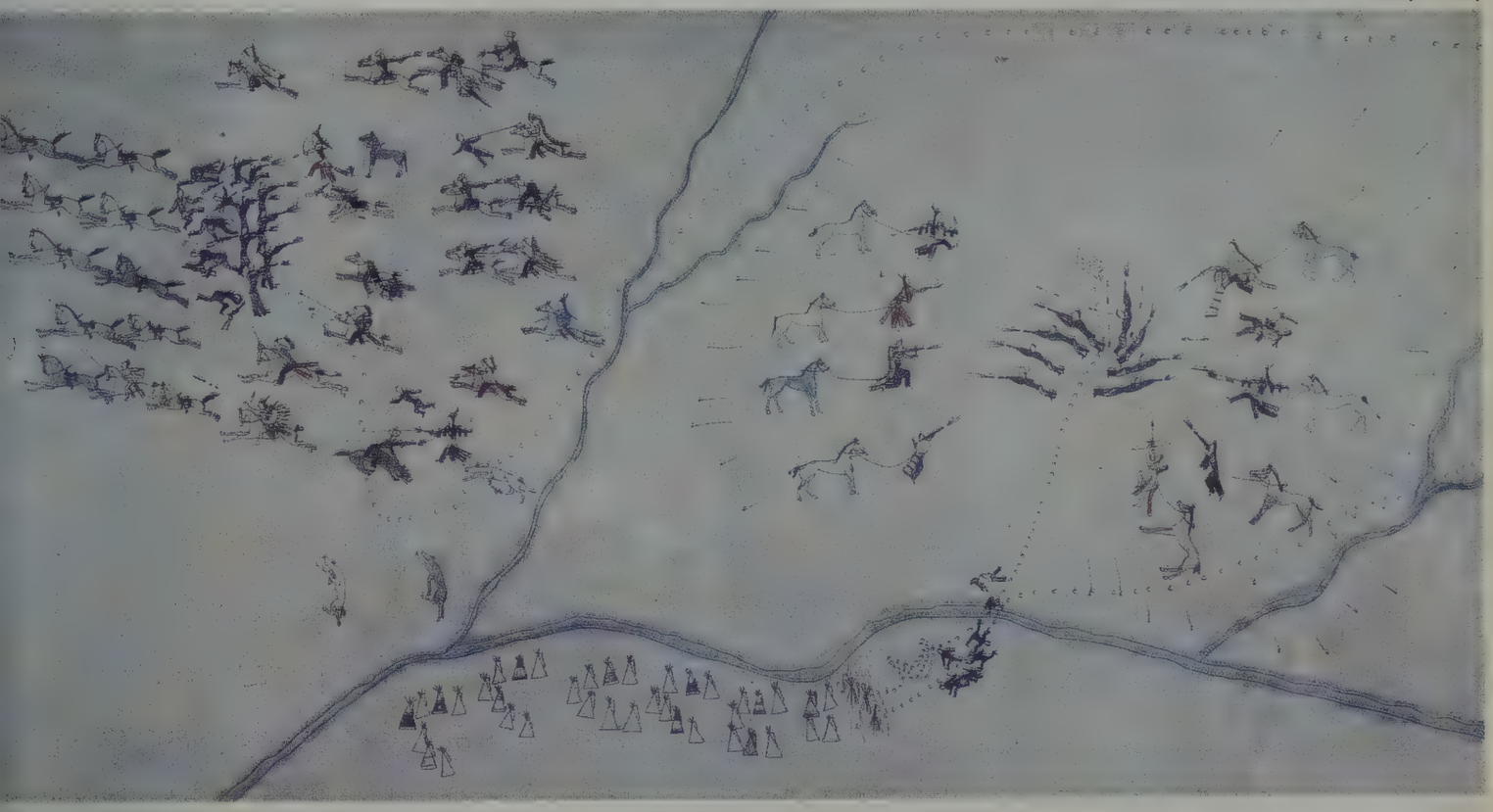
By using crime laboratory firearm identification techniques, we could dete mine how many individual weapons we represented by the archeological artifact We estimate that if 1,500 Indian warrio took part in the battle (a conservati number by historical accounts), the about 375 would have been armed wi muzzle-loaders and single-shot rifles suc as Sharps and Ballards, and about 19 would have been armed with repeati weapons. The rest may have used bo

urtesy of the Buffalo Bill Historical Center, Cody, Wyoming



he .44-caliber Henry, above, a sixteen-shot repeating rifle, was one of veral types of weapons used by the Indians. Below: White Bird, a northern heyenne who took part in the battle of the Little Bighorn when he was a boy f fifteen, painted the event about eighteen years after. Drawing on tribal nowledge, he showed the path of Reno's attack and retreat (at right), and uster's path and final position (at left).

West Point Museum Collections, U.S. Military Academy



nd arrows and a few old pistols and revolvers. Based on these minimal figures, ve can conclude that in terms of carbines, Custer's men were outgunned two to one.

There is historical information on the battle that derives from the examination f the battleground at the time of its discovery (including where the bodies of the fficers and men were found) and from ndian accounts. Combining this information with the distribution of the recently ncovered buttons, spurs, bullets, and cartridge cases, we are able to make a detailed reconstruction of the battle.

The Indian camp that Custer sought to ttack contained perhaps 3,000 to 4,000 people, including some 1,500 warriors. The Indians belonged to a number of different bands whose members were affiliated by common language and family ties. The majority were Sioux (Lakota, Teton, Brulé, and Blackfoot), a lesser number of Cheyenne occupied the northern end of the camp, and there were also a few Arapahos. Although camped together for protection, the various bands lacked an overall organization. There were a number of important leaders—Sitting Bull, Crazy Horse, and Gall for the Sioux; Lame White Man and Two Moon for the Cheyenne—but in battle, strategy was determined by individual initiative and charisma, not by a chain of command. According to Indian accounts, Sitting Bull, sometimes thought of as Custer's adversary in battle, did not participate in the fighting but occupied himself with making medicine to strengthen the Indian warriors.

Our reconstruction begins after the messenger left Custer, with the command apparently moving aggressively toward the Indian camp. Encountering Sioux and Cheyenne warriors directed by Gall at about 4:00 P.M., Custer moved north and gained high ground at areas now known as Greasy Grass Ridge and Custer Ridge. Here he deployed one company, led by Lt. James Calhoun, in a broad, south-facing arc some 400 yards long. Then, probably to confront a group of Indians attacking from the north and west, Custer took the rest of his men and wheeled north. Leaving Capt. Myles Keogh in charge of a company between himself and Calhoun, Custer deployed his remaining three companies between a high point and a ravine, now called Last Stand Hill and Deep Ravine, respectively.

These deployments formed a broad V-shaped pattern—a classic offensive formation—with the angle to the north, at Last Stand Hill. The cartridge cases attributed to the soldiers are generally in the area of this V. There is very little archeological evidence to document any further troop movement. Although the fight may have been a running one until this final deployment, after this, the units apparently stood their ground.

We determined the soldiers' positions from the presence of spent cartridges from government-issue guns. Bullets fired from the soldiers' guns were found embedded in the ground, often within, or in front of, the areas in which quantities of Indian cartridge cases were found. Bullets corresponding to the calibers of cartridge cases at Indian positions were found embedded in army positions. A few were associated with human remains.

The most intense Indian fire came from a position about 300 feet southeast of Calhoun's position, where perhaps as many as

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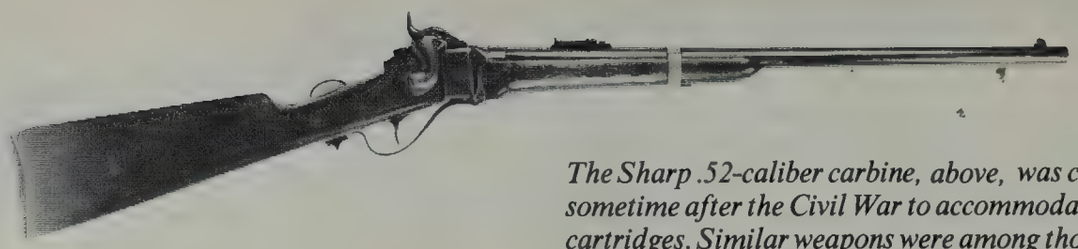


The Sharp .52-caliber carbine, above, was converted sometime after the Civil War to accommodate rimfire cartridges. Similar weapons were among those used by Indian warriors who fought Custer.

sixty .44-caliber Henry and Winchester rifles were being fired. A second Indian position, on Greasy Grass Ridge, was southwest of Calhoun's men. A minimum of forty-five guns using .44-caliber rimfire ammunition were fired here, as well as at least seven other types of weapons. Calhoun's men probably were overrun by Indians firing from these two positions.

The only physical evidence we found for any movement among the soldiers' positions consists of some .45-caliber cartridge cases (U.S. Army issue for the Springfield carbine), fired from the same weapons. These were found, first, in the Calhoun position, then scattered along a line toward the Keogh position, and finally, intermixed with cartridges belonging to the Keogh group. Several of Calhoun's men, watching their comrades and then their position fall, must have finally retreated under fire to Keogh's position.

Some Indian weapons fired toward Calhoun's men were also fired toward the cavalry line that stretched from Deep Ravine to Last Stand Hill. This cavalry line was also under attack from the north and west by Crazy Horse, Two Moon, Lame White Man, and other Sioux and Cheyenne warriors. Judging by the numbers of cartridges that we found, these warriors were not as well armed as those fighting Calhoun's men. Indians joining the attac from the south, after Calhoun's positio collapsed, may have added the firepow and numbers needed to overwhelm th cavalry.

The documented movement of a nur ber of Indian weapons indicates that as th battle progressed, the Indians move upslope toward Custer's final position o Last Stand Hill. Some of the Indians co verged at a knoll north and east of the h to shoot down into the knot of remainin men. We found little evidence that th soldiers fired their handguns. Indian a counts of the battle, gathered many yea afterward, state that the soldiers only use

A recent painting by Eric von Schmidt, below, reconstructs the Battle of the Little Bighorn from the point of view of the cavalry. Depicted along with Lt. Col. George A. Custer (right foreground) are others whose bodies were found on Last Stand Hill. His adjutant, Lt. W.W. Cooke, pistol in hand, falls near Custer. Custer's brother, Capt. Thomas W. Custer (foreground, left of center) crawls toward the pennant bearer (center).

Here Fell Custer © 1976, Eric von Schmidt. World rights reserved.

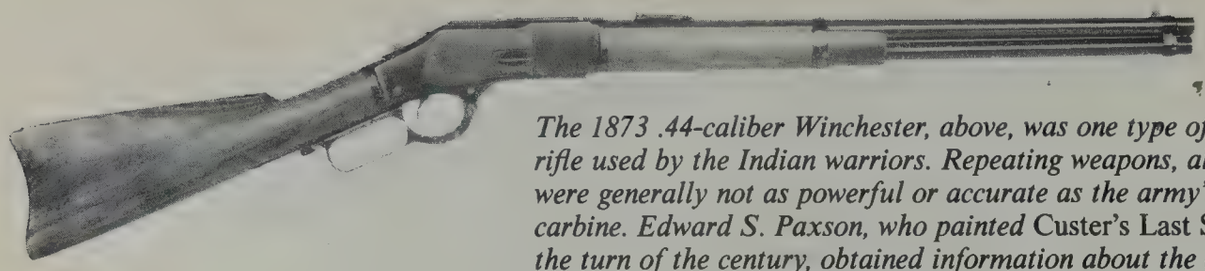
heir Colts near the end of the battle, when and-to-hand fighting began, and that af- er emptying their Colts, the soldiers did ot have time to reload before the Indians vere upon them. The paucity of Colt bul- ets and casings among the archeological inds confirms these accounts. The battle vas all over sometime between 5:00 and :00 in the afternoon.

Our excavations around the markers confirm that most were placed where a oldier fell, as shown by pieces of uni- orms, weapons, and human bone found nearby. About thirty-eight pairs of mark- rs (markers placed by twos around the battlefield) usually indicated a single sol- dier, thus accounting for many of the ex- cess markers.

Although Custer's men were reburied in a mass grave in 1881, we found human remains belonging to at least thirty-two individuals. Dr. Clyde Snow, a forensics expert who is interpreting the remains, says this is not unusual. Whenever un- trained people gather up bones, they may overlook small ones, such as hand and foot bones, or not recognize them as human. These were most of the bones we found.

The skull fragments we uncovered showed that the bone had been broken while still green, indicating what Dr. Snow calls "perimortem blunt instrument trauma." An Indian warrior, Black Elk, recounting the final moments of the bat- tle, described how the Indians used hatch- ets and clubs to finish off the surviving soldiers. While some of the evidence of trauma we found was undoubtedly in- duced at the time of death, many of the cut marks and crushed skulls may have resulted from mutilation of the dead, a normal cultural expression of victory for Sioux and Cheyenne warriors. This battle was not exceptional in this regard, but to the soldiers who buried Custer's dead on June 28, 1876, the field was a scene of ghastly and sickening horror.

The excavations around one pair of



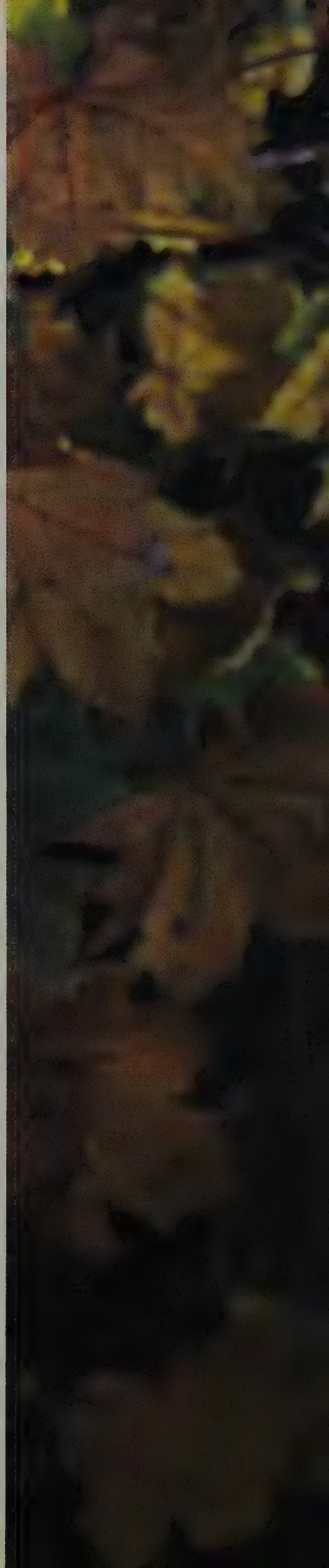
The 1873 .44-caliber Winchester, above, was one type of repeating rifle used by the Indian warriors. Repeating weapons, although faster, were generally not as powerful or accurate as the army's Springfield carbine. Edward S. Paxson, who painted Custer's Last Stand, *below, near the turn of the century, obtained information about the arms, uniforms, and equipment used in the battle from Gen. Edward S. Godfrey, who had been a lieutenant in one of Major Reno's companies.*

markers near the Deep Ravine yielded many bones from one individual, some uniform buttons, bullets, and a metal arrowhead. Taking this data, the relative placement of the artifacts, and a little imagination, we could put together the following scenario. The soldier was about twenty-five years old and robust—probably strong for his 5′8″ stature. He wore regulation coat and pants and was hit by a bullet from a .44-caliber repeating rifle. The bullet was associated with a few rib bones, suggesting the shot was to the chest and may have been the mortal wound. Whether the man was dead or dying, someone also shot him in the head with a Colt revolver. When the Indians overran his position, they crushed his skull with a war club and hacked at his front and back with knives. The Indians did not remove his uniform for cloth; perhaps it was too bloody to be worthwhile.

So far the archeological data support much in the Indian accounts of the battle and contradict none of them. As the analysis of the material collected in 1985 progresses, we will learn more details of Custer's fight, as well as what happened to Reno and Benteen. The archeological finds provide historians with a new resource in the study of the battle. By itself, each button, bullet, or cartridge may seem unimportant, but both the Indians and the cavalry left behind arrangements of artifacts that reflected their fighting styles, their ideas of leadership, and their concepts of battle.

The Battle of the Little Bighorn epitomized the clash of cultures—the Native American versus the Euro-American—that differed in hundreds of ways, including perceptions of land ownership, treaties, and boundaries. It may not have been of strategic importance in military history, but it did affect the course of this struggle. In the years preceding the battle, individuals sympathetic to the Indians' plight had determined government dealings with them. If the debacle at the Little Bighorn did nothing else, it galvanized the anti-Indian forces in the U.S. government, influencing official policy toward the Plains Indians until nearly the close of the nineteenth century. □

Courtesy of the Buffalo Bill Historical Center, Cody, Wyoming



A rufous-phase screech owl sets out from its nest box.
Joe McDonald

Odd Couples of Suburbia

The female eastern screech owl and her more diminutive mate are among the breeding couples of the suburbs

by Frederick R. Gehlbach

It is 8:00 in the evening on a typical late May day in central Texas. I sit thirty feet from a screech owl nest box in a suburban front yard. Inside are three downy chicks. Their mother warms them, while her third mate of the year roosts in a red cedar twenty feet away. He is somewhat larger than his two predecessors, both of which were killed by cars on the busy street, and I am anxious to learn what kind of food provider he is.

Like many raptorial birds, male eastern screech owls (*Otus asio*) furnish all the food to their mates during incubation and brooding, which are the responsibility of the female alone. Another characteristic that screech owls have in common with most raptors is that the males are considerably smaller than the females. The female screech owls I study are, on average, 17 percent heavier than their mates.

Every raptor biologist seems impelled to theorize about why the usual sex–size difference is reversed in hawks and owls, and I am no exception. Over the years, I have discovered that at least some female screech owls choose their mates from among the smallest males available, and I have been trying to find out why. Do the smaller males perhaps capture smaller prey or consume less food overall, and if so, how might this benefit the females and nestlings?

For the past nineteen years, I have been conducting a comparative study of the life history strategies of suburban and rural screech owls in and around Waco, Texas. Screech owls thrive in some suburban environments, especially those with good-sized, wooded lots. As part of my study, I closely monitor twelve to fourteen nests annually. Nearly every night, I watch the activities of at least one nesting pair for two or more hours. And I visit each active nest every five days, noting the weight changes of its occupants, stored food, and other basic information of incubation, brooding, and nestling development. All of this is especially easy to do in suburbia, where eastern screech owls are used to hubbub and quickly conditioned to my obtrusiveness.

Furthermore, screech owls are easier to locate in suburbia, where they are up to five times more crowded than in the countryside. Typically, a rural pair of screech owls range over about seventy-five acres of greensward; a suburban pair occupy ten to fifteen acres. Suburbanites in my study area have replaced more than half of the original wooded landscape with buildings, streets, and driveways, restricting the cavity-nesting owls to lawns and parks with at least some mature trees. (In some suburban yards, friendly homeowners—or researchers—have also set up nest boxes.) The number of trees per acre ranges from 132 in the suburbs to 438 at my rural study areas; perhaps the biggest vegetational difference is the 75 percent reduction of shrub cover in suburbia.

At 8:11 P.M. the female appears at the entrance hole, as her mate flies to his usual food-delivery perch eight feet in front of the box. A mourning dove stops singing, but across the street, lawn mowing continues, and every two minutes a car passes by. Three joggers run by, dogs bark in response, and a passing motorcycle causes the female to duck inside the nest box.

Bob and Clara Calhoun; Bruce Coleman, Inc.

Below: A week or so after leaving the nest, a screech owl fledgling begins to catch insects on its own. Right: The ringtail cat, a common denizen of suburban and rural Texas, is the most formidable predator of nestlings and eggs.

John Netherton

The male dumps a headless common grackle in the entrance hole and departs. By 8:25 it is dusk; neighborhood lights are on. The female leaves the box for twenty minutes, swoops across the street, defecates, and takes a drink from a birdbath. Next morning the grackle is two legs and some feathers added to the nest debris.

Annually, my study begins in late January or early February when male screech owls begin to reclaim ownership of one or a few permanent roosting-nesting cavities or nest boxes. Their lifelong mates may remain through the winter but move short distances if harsh weather and food shortages force a pair to split up. The winter diet includes birds up to the size of a mourning dove and rodents no larger than black rats. Smaller birds, however, such as house sparrows, dark-eyed juncos, and pine siskins, are the most common winter foods. As the breeding season progresses, birds and mammals give way to insects and reptiles in the owls' diet.

Suburban pairs overlap slightly in their hunting ranges, and because males defend only the cavities and areas in the immediate vicinity, they sometimes nest in boxes only 150 feet apart. A sweet, melodious, monotonic trill is their chief signal of cavity ownership. They may switch to the more familiar, descending trill during territorial disputes, especially in late summer and fall when a number of dispersing youngsters are about. The seasonal shift from monotonic to descending trill is very pronounced, and I sometimes hear both members of a pair trilling antiphonally. Such back-and-forth singing is often low in volume and misleadingly ventriloquistic, making the birds sound farther away than they are.

The screech owl's vocal repertoire is actually quite rich. Some authorities claim these owls do not screech, but they definitely do so if frightened. Known predators elicit hoots of alarm or barks that presage physical attack. Small nestlings peep like domestic chickens; larger ones chatter when jostled, as do adults when mobbed by songbirds. Large nestlings also give rasping calls when begging for food. And, like owls generally, all disturbed screech owls clap their bills.

Vocal differences between males and females provide a clue to understanding sex roles in this species and, ultimately, the significance of reversed size dimorphism. The males, for example, have lower-pitched voices than the females and are most likely to trill, a vocalization generally used when communicating with their mates or proclaiming ownership of cavity. Females are more apt to hoot an bark, for example, when they are defend ing their family.

March 24 is the average date for th first suburban egg of the year, four day earlier than the first rural egg. Female reoccupy nesting cavities for several day prior to laying, and about 70 percent begi incubation as soon as the first egg is laid The first three eggs are laid at one- to two day intervals, the fourth and later eggs a two- to three-day intervals. In both th suburbs and the countryside, the usua clutch consists of four eggs, but clutch siz

ranges from two to six, with bigger and older females laying larger clutches.

During an incubation period of about thirty days, females leave their clutches for ten to twenty-five minutes at a time, usually at dusk, but sometimes also near dawn. Incubating females spend most of their time sitting quietly on their eggs; even when I open nest boxes, most remain still, squint-eyed, and with ear tufts erect. This behavior may lead a predator to overlook a dark bird in a dark cavity. When handled gently, such females can be lifted off and replaced upon their clutches without incident. But if handled roughly, as I have done to simulate a ringtail cat, central Texas's foremost predator of suburban and rural screech owl nests, females kick their all-white eggs into the open, where they are conspicuous against the dark nest debris, and lie on their backs with talons erect. No wonder few nesting females are killed by ringtails, while annual egg mortality averages 46 percent. (Only 16 percent of nestlings die, but because of increased predation, the rate is 2.7 times greater in the rural population.)

The male feeds his incubating and brooding mate assiduously every time she leaves the nest or by depositing food directly in the cavity. This is demanding work. How does he do it? Interestingly, males are not only smaller than females, but their wing loading (that is, body weight per unit wing surface area) is also about 25 percent less. As a result, they ought to be able to deliver more loads with less energy expenditure or carry heavier prey. Since I do not detect any sexually related size difference in prey during either the nesting season or the winter, I propose that small males simply need less food for themselves and can give more of what they catch to their mates, which are totally dependent on them during the five-

Joe McDon

Right: A female approaches her nest box to resume incubation duty. Before the eggs hatch, females generally leave the nest only once a day, usually at dusk, to get a drink or to defecate. Below: For the first few days after fledging, and before they have mastered the rudiments of flight, owlets often sit near one another in a tree. There they are fed, and vigorously defended, by their mother.

Steven D. Faccio

week period of incubation and brooding. The sensible choice for the female, then, is a small mate, and indeed I find that females that lose the least weight during nesting are the ones that raise the most young to fledging.

In fact, females with the longest nesting records are the heaviest; those found nesting only once in my study areas are smaller than all others. Also, my records show that the female nestlings that survive to become breeding adults are apt to be significantly larger—at the time of banding—than their nest mates. This suggests that size has long-term survival value in the eastern screech owl as it does among a number of birds (my oldest breeding bird is an eight-year-old female; average life span is 3.6 years). Unfortunately, getting comparable data on males is difficult; the vast majority of banded nestlings that I am later able to identify as breeding adults are females. Perhaps males disperse farther; they must seek out new, unoccupied terrain, while at least some females settle closer to home, accepted as mates by older, established males.

It is 8:20 P.M. on an evening in the first week of June, and the female, no longer brooding, comes to the box without food, looks in as if to check things out, and departs. (She is easy to recognize because I have dyed her tail tip yellow.) The male leaves his perch in the red cedar almost simultaneously and flies off in the opposite direction. Until about 9:15 P.M. the lingering light permits me to watch the pair catching moths and katydids on tree foliage and June bugs (beetles) and crickets on the ground within a 300-foot radius of the nest. The box itself is illuminated by a porch light, so I have no difficulty seeing each food delivery and determining the identity of most items. Also, the adults rarely fly directly to the nest with food; usually they sit for a few seconds on a perch near the box, which allows me to get a good view with 7 × 42 binoculars.

Of sixty-six food-gathering flights I monitor this particular night, fully one third are only 75 to 150 feet in round-trip length, and another third are no more than 325 feet. The shortest trips never go beyond the 100-by-40-foot front yard in which the nest is found; slightly longer ones include the yards next door and across the street. Food supplies in suburbia are two to eight times more concentrated than in the rural environment, which is surely the reason for such small hunting ranges.

While the parent owls often hunt in opposite directions, once a food source is located, both birds fly to and from it repeatedly. For instance, June beetl drawn to lights attract the owls, whi make twenty-one sorties to one patio lig tonight. The birds swoop low from the ne cavity or a perch, fly three to eight fe above the ground, and then rise abrupt to another perch from which they poun on the insects. (Swooping low may perm unobstructed travel under the tree ca opy, but it certainly gets screech owls in

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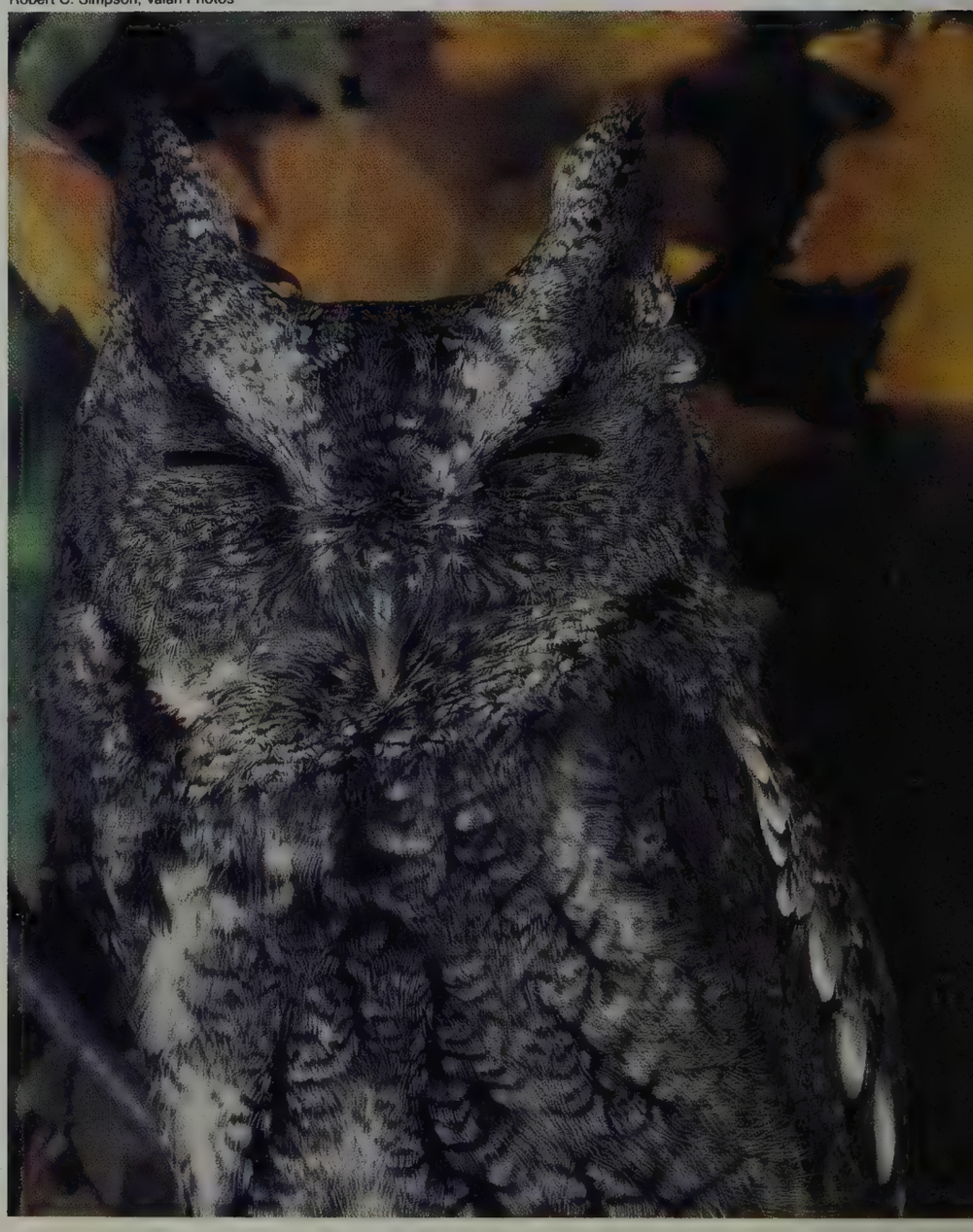
Screech owls, such as this gray-phase bird, normally roost from dawn until dusk, during which time they perch quietly in a tree cavity, on a limb next to a tree trunk, or in a tangle of vines.

Robert C. Simpson; Valan Photos



trouble crossing streets. Moreover, the birds catch earthworms on wet pavement, even during rain, which further explains why vehicles are their great nemesis.)

The owls also pursue some six species of small serpents. One, the Texas blind snake, is brought in alive and lives in the debris at the bottom of the nest. Perhaps the blind snake's smooth cylindrical body and writhing defensive behavior protect it, since eastern screech owls always try to kill and usually decapitate vertebrate prey. Once it has slipped out of the owl's talons, a blind snake burrows about in the leaves, rotten wood, nestling fecal piles, pellets, and stored food that litter the nes eating fly and other soft-bodied insect la vae. Curiously, owlets in nests with live-i blind snakes grow faster and are mor likely to survive to fledging than othe broods of the same size and in the sam year, perhaps because larvae eaten by th snakes might otherwise parasitize th nestlings or compete with them for food

I observe that in all nests fast growt and a relatively short nestling period ar related and that these two factors, in turn are always associated with low nestlin mortality. (Suburban nestlings grow faster than their rural cousins, and on

sult is that breeding success is signifi-
ntly higher in suburbia.) Cannibalism
nong the siblings, starvation, and suffo-
tion are the main causes of death at this
age, although predation is important in
e country. Just how rapid growth leads
breeding success became clear when I
arned that the last-hatched, smallest
stling grows especially fast. It quickly
tches up to its bigger brothers and sis-
rs and hence is less likely to be eaten,
nothered, or put last in line for food. And
hen all the owlets grow fast, they all
perience shorter nestling periods, which
ves predators less time to discover them.
After an average of twenty-seven days,
wlets are ready to leave the nest. They
edge in the order in which they hatched,
ne or two a night. Hunger is a major
centive in large broods and among last-
atched chicks. When the nestlings ap-
roach fledging weight, which is heavier
suburbia than in the countryside, the
arents deliver less food, and the youngest
wlets lose weight. And as soon as one has
ft the nest, the others certainly lose
eight, since the parents devote most of
ieir attention to fledglings.

In contrast to their passivity during in-
ubation, adult screech owls, especially
emales, actively defend older nestlings
nd fledglings from predators and other
uisances. A few days before they fledge,
estlings spend much time looking out of
ne cavity entrance, so I always know what
o expect next. A hard hat and glasses are
ow in order if I want to approach closer
han fifty feet or so, because some males
nd nearly all females will attack at this
ime. Once a female hung from my ear
obe by one talon—momentarily!

Adults, again especially the females,
ften vocalize before attacking, but not
lways, particularly when the interloper is
mall. A large eastern cottontail rabbit—
either predator nor prey—that inno-
ently hops too near the nest may find
tself attacked. I once watched an owl
ring a moth back to her nest just as a
abbit bounded into view. She delivered
he food, turned around in the entrance,
nd peered intently at the cottontail al-
nost directly below. Quietly, she swooped
n the apparently unsuspecting rabbit as it

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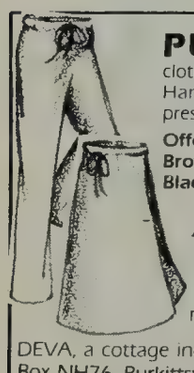
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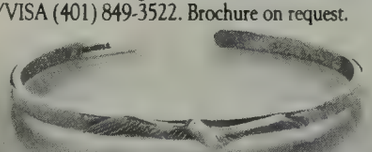
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An adult screech owl delivers a caterpillar to an approximately three and a half week old nestling. Once the young birds show themselves like this at the cavity entrance, fledging is only a few days away.

Steven D. Faccio

hopped beyond the nest tree and bopped it squarely on the back. The startled creature leaped two feet into the air and ran another fifty or so feet to the driveway. The male owl came by next but only made a low, silent pass over the rabbit.

Saving physical defense, and hence energy, for the time when the young birds are close to independence, and when it may be too late to renest successfully in the current year, makes sense to me. Breeding success is more closely related to number of fledglings than to clutch size, because lost nestlings are not replaced while clutches are. And for females to be the chief defenders is also logical because their extra weight allows a much harder strike. Some males do attack, but females do so almost invariably and usually first.

Thirty minutes of waiting on day 27, beginning at 8:15 P.M., has produced only an excited pair of trilling and hooting parents. No feeding so far. Do the adults sense that a nestling will leave? I have moved back fifty feet, but the female buzzes me. At 8:45, a nestling simply drops to the ground after hanging a few minutes by one leg from the entrance hole. It sits where it lands and is visited once by its mother, which has no food that I can see. She then flies to an oak twenty-five feet away, and the owlet follows hopping and flapping, covering one to five feet a time. On reaching the tree, the little b uses its beak, its feet, and its flappi wings to climb. (Fledgling screech ow like other owls and hawks I have observe cannot really fly for a few days.) Witl three minutes of leaving the safety of nest, the new fledgling sits eight f above the ground.

The next night I am back at my post 8:20, and the adults are busy feeding t lone fledgling, which now sits twenty-f feet above ground in its climbing tr They totally ignore loud, food-beggi calls from the two remaining nestlings. 8:55, number two chick leans way o weaves and bobs in customary fashi and hurtles eight feet through the air, l ing two feet in elevation, but landing o small tree trunk directly in front of t nest box. This one also climbs straight u Then the third owlet climbs out of t hole, up over the top of the nest box, a on up the large elm tree supporting Next morning all three fledglings are gether on a thin branch at the tiptop another elm close to the nest box. T oldest fledgling had moved about thi feet through the tops of at least two tre to reach its new position, where all a accompanied by their mother.

The female usually stays within a f

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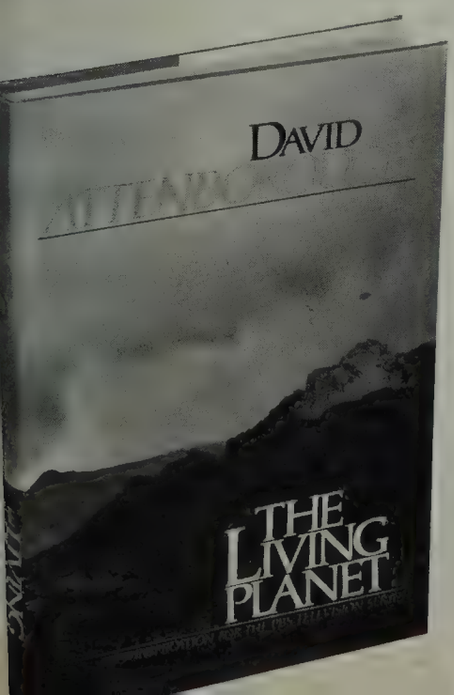

Jerry Bauer

feet of the fledglings during their first few days to two weeks outside the nest. Unlike adults, which normally roost at the base of a limb next to the tree trunk, in a vine tangle, or in a cavity, youngsters are liable to sit anywhere except in a cavity, and during these early days, the attendant parent does likewise. My close approach elicits an attack from the female, while her mate, if he happens to be nearby, watches wide-eyed or simply flies away. After about one week, fledglings fly moderately well, begin making clumsy attempts to catch insects, and may wind up separated from each other and from adults in the daytime. The young become increasingly independent but are tolerated and occasionally fed within their parent's hunting range for most of the summer.

Juvenile screech owls begin to disperse in late summer. All seem to be on the move by August or September, judging from the increase in the number of descending trills by resident males at this time. Recoveries of banded youngsters six to forty-eight months after fledging indicate movements up to nine miles away from natal areas, although most found as breeding adults have settled less than a mile from the nest box in which they were raised. A few rural owlets have been rediscovered nesting in suburbia, but not the reverse. This may be because food is more plentiful in the suburbs.

For many of the fledglings, life is short. For example, 71 percent of the suburban birds killed by cars between October and February are juveniles. Other youngsters fly into windows or are caught by predators, and some simply seem to starve to death during their first winter. Two cases are illustrative: a month after fledging, a young owl, attempting to catch an insect, strikes a lighted window and breaks its neck; it is only 250 feet from its nest. From the same nest box the next year, again almost exactly one month postfledging and but 400 feet from its birthplace, a juvenile is hit by a car and breaks one wing. In the rural environment a serious injury means certain death, but suburban owls are sometimes rescued by their human neighbors, some of whom are raptor rehabilitators.

By fall I am relatively free of fieldwork and can rethink my findings of the earlier years. Each season is a new test of old ideas. Regarding questions about reversed size dimorphism, my observations confirm that in any given breeding season, the smallest of the males tend to do most of the breeding. I predict that these males are the most efficient energetically a that this significantly contributes to productive success since it means m food for the female and her young. At same time, large size is an advantage females because they lay more eggs, r more offspring, and are the main defe ers of nestlings and fledglings.

If my ideas are valid, screech o might conceivably go on diverging in si But I think the species' habit of nestin cavities would probably select against males that were too big. In central Tex most of the cavities available to, and saf for, screech owls are small. Barn a barred owls, plus opossums, raccoons, squirrels, and ringtails, are potential pr ators and competitors for cavities, they require or prefer more spacious commodations. If a female is too big squeeze into a cavity selected and fended by her smaller mate, she may to reproduce; large size is, therefore, advantage only up to a point. Size div gence in screech owls (and most like other cavity-nesting owls and haw should thus focus primarily on males stead of females; and female choice o small, energetically efficient mate may the most critical selective factor in evolution of size dimorphism.

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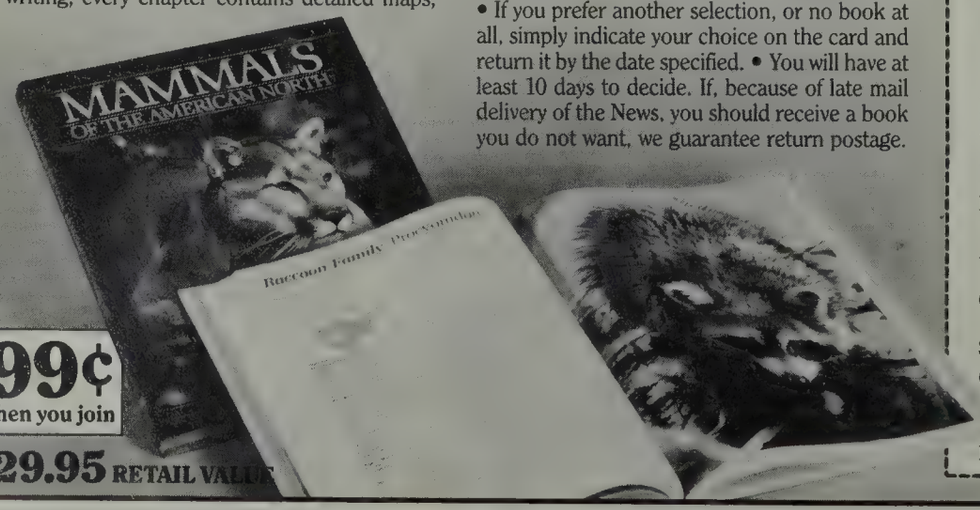

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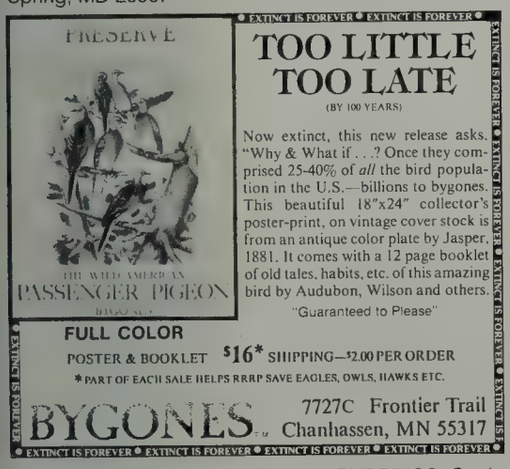
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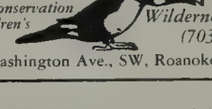

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Off the Main Drag

While other space probes headed toward Halley, a NASA craft made the first visit ever to a comet

by Stephen P. Maran

On September 11, 1985, the NASA space probe *ICE* (International Cometary Explorer) passed through the head and tail of a small comet. Measurements made by on-board instruments during this brief visit to Comet Giacobini-Zinner not only confirmed a theory of comet tails that was proposed in 1957 by Nobel Prize-winning physicist Hannes Alfvén but also revealed previously unobserved cometary phenomena, including the existence of beams of high-speed, electrically charged molecules and the generation of intense plasma waves (electrical and magnetic disturbances that resemble very low frequency radio waves).

Despite its name, *ICE* was not designed to visit a comet. At first, it wasn't even called *ICE*. When launched in August 1978, the spacecraft was named the International Sun-Earth Explorer 3 (*ISEE-3*). Nor was the probe designed to voyage 44 million miles from the earth, where it flew through Comet Giacobini-Zinner on September 11. Its modest original goal was a station only 930,000 miles from the earth in the direction of the sun. There, *ISEE-3* was to (and did) monitor the solar wind, the outward-flowing plasma (electrified gas) that comes from the sun's outer atmosphere, or corona. Two other craft, *ISEE-1* and *-2*, were placed in orbit to measure disturbances induced by the solar wind in the earth's magnetosphere.

The magnetosphere is the huge region of magnetic fields and trapped atomic particles that surrounds the earth outside the atmosphere. Its best-known components are the Van Allen belts, which were discovered by the U.S. satellite *Explorer 1* in 1958. Until recently, and perhaps even now, its least-known component has been the geotail, a magnetic formation that extends far beyond the moon's orbit on the side of the earth opposite the sun. Like a comet, the earth has a tail that always points away from the sun. Unlike a comet tail, however, the geotail is invisible, even with a telescope. Nevertheless, it can be investigated if suitable instruments, such as magnetometers (which measure magnetic fields) and plasma-measuring devices, are trailed through it by a spacecraft, like oceanographic sensors being towed behind a research vessel.

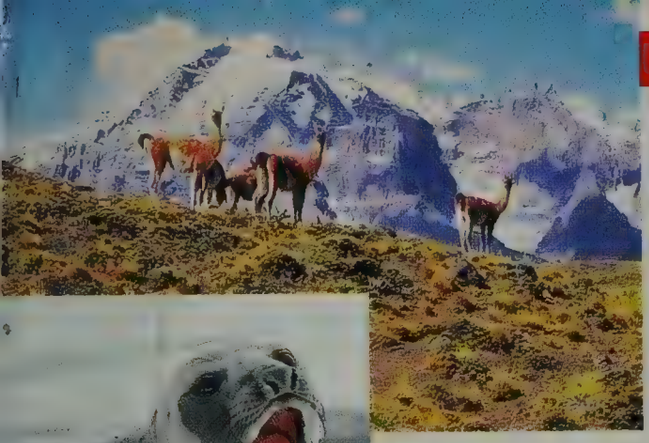
In mid-1982, *ISEE-3* was given a new assignment as an interplanetary explorer and was diverted from its sunward station to conduct the first detailed survey of the distant reaches of the geotail. The probe made two long sweeps through the geotail in 1983, mapping it to a distance from the earth about four times greater than the distance to the moon. Earlier satellites had gathered information on the properties of the geotail close to the earth, and a few deep-space probes had obtained fragmentary data while passing through the geotail at great distances from the earth, en route to other regions. These previous studies, however, could not prove whether (as some physicists believed) the geotail breaks up into distinct, long magnetic filaments at great distances from the earth, like a peacock's tail that divides into feathers, or whether (as other investigators proposed) the geotail retains its structure at great distances, like the long tail of an alligator. The *ISEE-3* survey validated the concept of a single long tail and, among many other observations, repeatedly found plasmoids sweeping down the geotail from the direction of the earth.

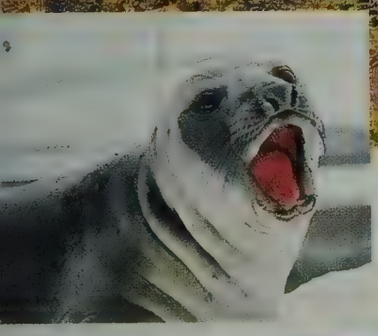
Plasmoids are huge, thin clouds of electrified gas, threaded by magnetic fields. I'm always tempted to call them "great balls of plasma." According to data from *ISEE-3* and from satellites orbiting closer to the earth, plasmoids are ejected from the magnetosphere at a point relatively close to the earth during geomagnetic storms, which themselves are triggered by solar flares or other disturbances on the sun. They fly away from the earth along the geotail and are so large that a typical plasmoid, as observed in 1982 and 1983, traveling at up to 2 million miles per h took up to thirty minutes to pass *ISE* The next mission of *ISEE-3* was to Comet Giacobini-Zinner.

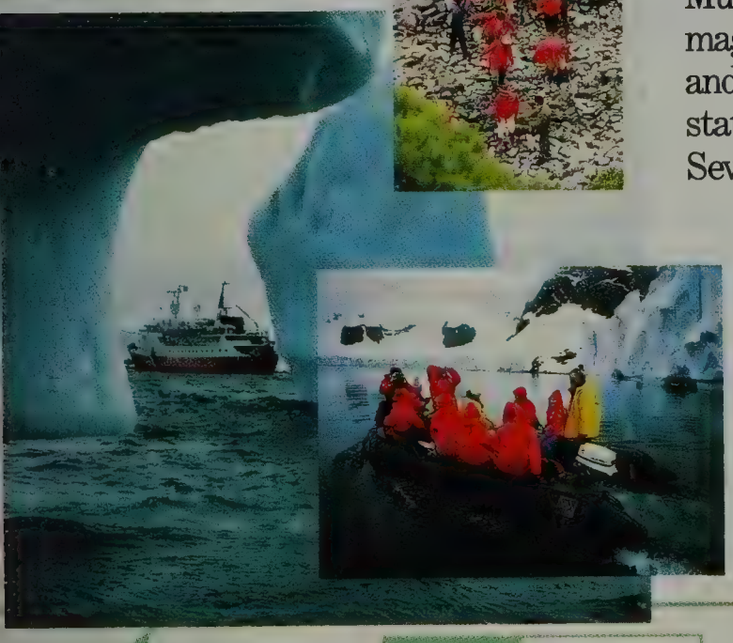
Spacecraft such as *ISEE-3* are not ily diverted from their paths. Few c have enough rocket fuel on board or o means of propulsion to enable them t around the cosmos at a ground control (or pilot's) will, a luxury available onl Buck Rogers, Han Solo, and other s space heroes. *ISEE-3* was twice direc down the geotail and later sent or Comet Giacobini-Zinner by means of nar gravitational assists, a technique uses the moon's gravity. The probe's w on-board propulsion was employed onl fine tune *ISEE-3*'s trajectory and to the probe in the desired direction.

To slow down a spacecraft with lu gravity, engineers send the craft on a jectory that takes it past the leading he sphere of the moon (the side that fa forward as the moon moves along its o around the earth). But to accelerate craft, engineers must order it past the positely directed, or trailing, hemisph To survey the geotail and visit the com *ISEE-3* had to be swung past the m five times. On December 22, 1983, in final lunar swing-by, the craft skimm within just seventy-five miles of the lu surface, picking up enough speed to hu out to meet Comet Giacobini-Zinner September 1985. When *ISEE-3* flew of the earth–moon system on a path ward the comet, it was renamed *ICE*.

Early on the September morning *ICE*'s encounter with Comet Giacob Zinner, I was sitting at the fore o NASA auditorium. Behind and above a large projected image of the comet marked to show the position of the spa craft as it made its final approach. Link by voice lines to the control center a other key points and surrounded by mo tor screens displaying data from probe, as well as images of the comet fr







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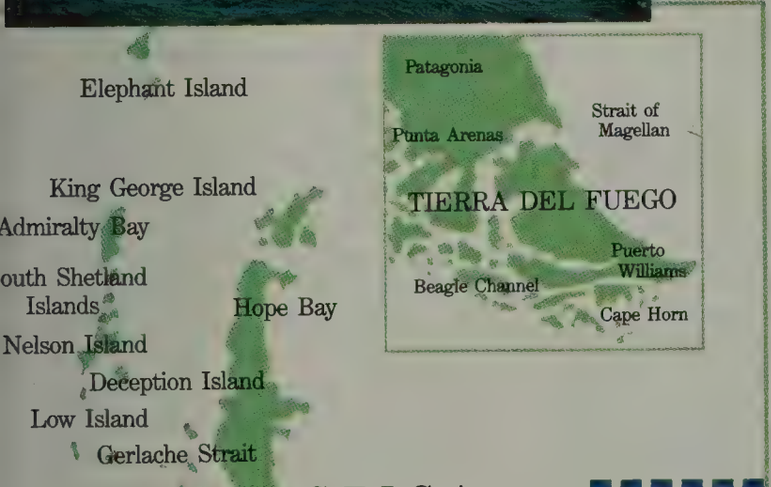

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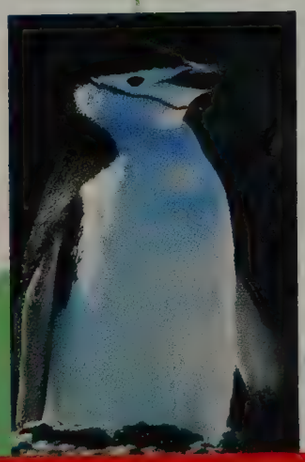

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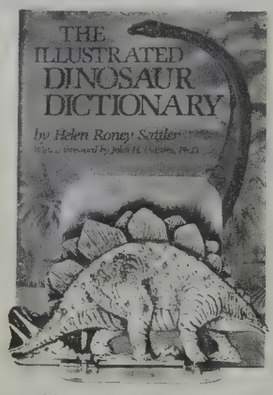

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ground-based observatories, I had the task of describing the events of the encounter to an audience of scientists, NASA officials, and members of the press. Like many in the room, I was very much in suspense. As it neared the comet, *ICE* was about fifty times farther from the earth than it had originally been designed to travel, and as a result, its radio signals were very weak. Even should *ICE* successfully penetrate the comet, the radio telemetry of measurements made during the event might be too weak to be recorded on the earth.

There were other concerns. A comet's tail or at least the part known as the plasma tail (it glows in blue light, as shown in color photographs of comets, while the other component, called the dust tail, shines yellow by the reflected light of the sun) waves up and down in the solar wind, like a wind sock at an airport. This plasma tail was the very part of the comet that *ICE* scientists wished to investigate, but would the tail wave off in the wrong direction when it was too late to make any final adjustment in *ICE*'s trajectory? Even if the spacecraft went through the tail, would its payload, built to monitor the solar wind, obtain meaningful data on the comet? Some scientists doubted that it would. Finally, mission engineers feared that dust particles from the comet, even if individually too small to damage the spacecraft, might yet blanket *ICE*'s solar cell panels, which power the scientific instruments, radio transmitter, and other spacecraft systems. Coated with dust, the panels would generate little if any electricity. In that event, no data would be returned to the earth. All of these fears proved to be unwarranted. The spacecraft went through the plasma tail, much data was obtained and returned to the earth, and there was no measurable drop in *ICE*'s electrical power generation during the comet encounter.

Scientists had predicted that as Comet Giacobini-Zinner and other comets moved through the solar wind they would be accompanied by moving disturbances called bow shocks, much as the Concorde is preceded by a sonic boom when it exceeds the speed of sound. Such bow shocks have been found to accompany the earth and some other planets as they travel through the solar wind, which pervades interplanetary space. This prediction seemed to have been verified about 4:30 A.M., EDT, on that September morning, when Fred Scarf, an investigator of plasma waves at the aerospace firm TRW, Inc., in Redondo Beach, California, reported that his plasma-wave receiver on *ICE* had detected the apparent signature of a bow shock. Almost immediately, word came in that this and other on-bo instruments were registering very high nal levels, indicating that *ICE* had ente a zone of intense radiation and turbul plasma. The spacecraft was then m than 110,000 miles from the comet. about the same time, word came that p tons apparently associated with the co were streaming in a directed manner, w about 400 times as many protons flow one way as flowed in the opposite di tion. (Protons are positively charged pa cles and in most cases are the nuclei hydrogen atoms that have lost their ass ated electrons.)

At about 7:00 A.M., shortly before *I* was due to pass through the central par Comet Giacobini-Zinner's plasma t Goddard comet specialist Malco Niedner excitedly told me from the c trol center: "We're beginning to det field draping." This was the first indi tion that the theory proposed by Han Alfvén of the University of California San Diego would be confirmed. Acco ing to this theory, the distinctive, narr shape of a cometary plasma tail is due the confinement of plasma from the he of the comet by a hairpin-shaped ma netic field. This configuration suppose forms when magnetic field lines in t solar wind encounter the electrified atm sphere in the head of the comet and be around it (hence "field draping"). Edwa J. Smith, the interplanetary physicist the Jet Propulsion Laboratory in Pa dena, California, who built the ma netometer carried by *ICE*, found t draped field lines in the comet's plasm tail bore out Alfvén's predictions, though the strength of the magnetic fie was greater than expected.

Despite the first indications fro Scarf's instrument, analysis of data fro various *ICE* instruments by Smith a others did not confirm the presence of bow shock. There was indeed a major d turbance around the comet at about t location where a bow shock had been pr dicted, but the detailed mapping of t disturbance by several instruments did n jibe with previous surveys of planeta bow shocks. Normally, the speed of t solar wind changes from supersonic subsonic as the wind crosses a bow shoc and this transition occurs over a narro region. But around Comet Giacobi Zinner, there seems to be a broad intera tion zone in which the solar wind may slo down gradually as it encounters lar numbers of heavy electrified molecul from the comet. Further understandi will require measurements from oth comet probes.

Within the plasma tail of the comet, the *CE* instruments found that the plasma vas cooler and less turbulent than in the road interaction zone or in the solar wind ar from the comet. One instrument, designed to determine what substances were present, detected ionized water vapor with chemical formula H_2O^+), a substance known since 1973 to occur in comets, and also found the related molecule H_3O^+, known as hydronium, whose presence in comets had been predicted, but not previously verified.

To me, the single most notable finding of the *ICE* mission was the detection by instruments from the Imperial College in London and the Max Planck Institute for Extraterrestrial Physics in Garching, West Germany, of heavy electrified particles called pickup ions (because they have been, in effect, picked up by the solar wind), streaming through interplanetary space at distances of up to 2.5 million miles from the comet. These particles seemed to be flowing systematically away from the sun, rather than away from the comet, but the *ICE* investigators nevertheless concluded that the particles derived from the comet. Although logic would attribute them to solar emission, extensive studies of the solar wind, including a seven-year study by *ICE*, revealed no such molecules until *ICE* neared Comet Giacobini-Zinner. This points to the comet as the origin.

The present theory holds that the observed, electrically charged molecules were shed by the comet's solid nucleus, the so-called dirty iceball, as neutral (not electrified) molecules. As neutral particles, they were not confined by magnetic fields and accordingly were not channeled into the comet's plasma tail. Instead, they flew outward into space, some traveling toward the sun. As the latter approached the sun, they were ionized (electrically charged) by the action of solar ultraviolet light. Once ionized, they were subject to forces exerted by the solar wind, which reversed their paths, pushing them away from the sun.

Thus far, *ICE* has had two names and carried out three missions. It has monitored the solar wind on the sunward side of the earth, surveyed the earth's geotail, and made the first visit of a spacecraft to a comet. Despite initial doubts and some fears, the scientific return from the first comet visit surpassed all expectations.

Stephen P. Maran is a senior staff scientist in the Laboratory for Astronomy and Solar Physics at NASA's Goddard Space Flight Center in Greenbelt, Maryland. The opinions expressed here are his own.

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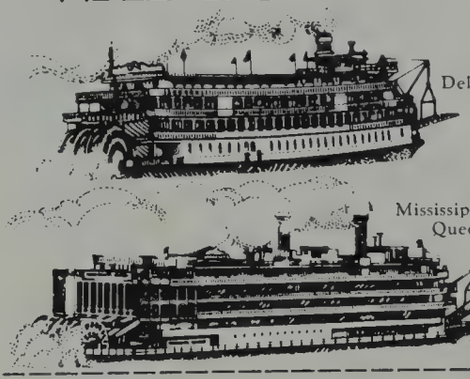

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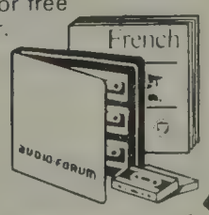

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Hooray for Mars

by Thomas D. Nicholson

Mars qualifies easily for the June Planet of the Month award. It has brightened rapidly this spring as the July opposition approaches, and by month's end it is virtually as bright as Jupiter. Both planets are morning stars, so you can compare them visually and note the difference in their relative brightness from the beginning to the end of June. Mars, in Sagittarius, is far enough east of the sun to be in the sky from early evening to dawn. It rises before midnight early in the month; soon after 9:00 P.M. in late June. Jupiter rises in Pisces after midnight and appears only in the morning hours. The other planets are evening stars all month.

Before Mars rises, the evening sky is dominated by brilliant Venus, also near its greatest brightness. It appears at dusk, coming out of the twilight in the east, and it stays there until shortly before Mars rises in the east. Since Mars remains visible until dawn, when it shares the sky with Jupiter, June nights this year are graced with bright planets.

Saturn, in Scorpius, also adds to the evening scene. Well up in the south after sundown, Saturn sets soon after midnight. Mercury is well enough placed late in the month to provide a fair chance of seeing it in the early evenings, when it will be low in the west after sunset, below and to the right of Venus.

The best planet shows of the month will appear in the mornings when both Mars and Jupiter are up. It will be worth rising early to see the two planets, especially late in the month when the moon will also be present. Jupiter will be high in the south, Mars will be setting in the west, and the waning gibbous moon will be somewhere between them from the 23d to the 27th.

Events in the calendar below are given in local time unless otherwise indicated.

June 1: The crescent moon and Jupiter rise about an hour and a half after midnight and remain to greet the dawn. Jupiter leads as they climb the sky. There is no evening moon until the 8th or 9th.

June 2–5: Closing on the sun, the moon rises later in the morning day by day, slimming noticeably. Mark its location relative to the rising sun and see if you can pick it out in daylight until it sets in the afternoon.

June 6–7: Apogee moon (farthest from the earth) is on the 6th; new moon (at 9:00 A.M., EST) is on the 7th.

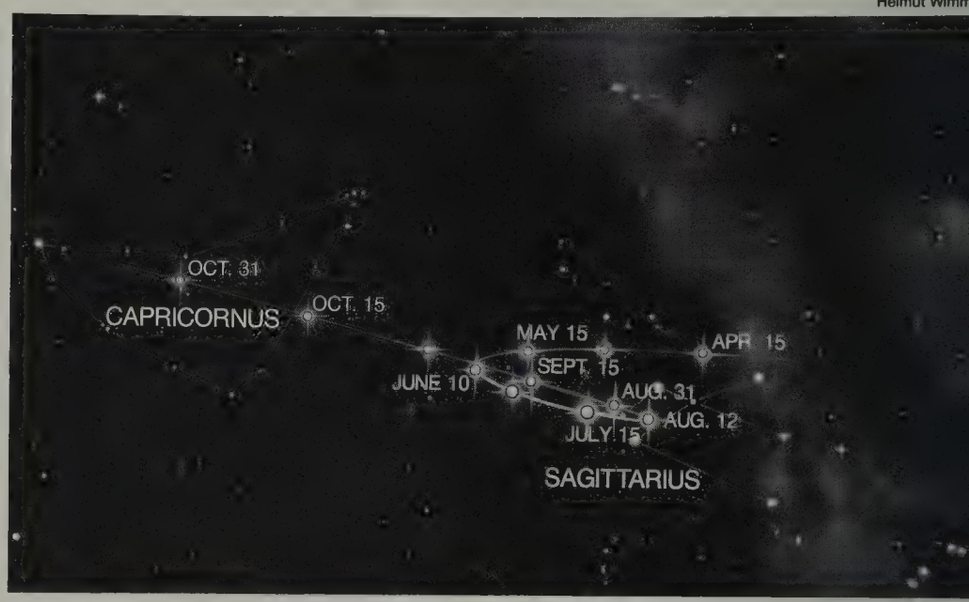
June 9: Mars begins its westerly (retrograde) swing through Sagittarius, anticipating the forthcoming opposition from the sun. Look for the slender, graceful young moon in twilight. It sets in the west at about 9:00 P.M., EST.

June 10: The moon's conjunction with Venus is at 11:00 A.M., EST, and the two are close in tonight's sky.

June 13: Leo's Regulus is the bright s near the moon.

June 15: The first-quarter moon che in at 7:00 A.M., EST. The slightly gibb moon is very near the autumnal equino dusk, high in the south. Note that position of the moon (and the equinox very nearly midway between Regulus the right) and Spica (to the left in Virg Both are easy marks to help locate equinox, where the sun is located on first day of autumn.

Helmut Wimm



This summer will bring the best view we have had of Mars in the past fifteen years and will have for the next seventeen years. Not since 1971 has the planet been so bright; not until 2003 will it be as bright again. Its brightness will peak in the autumn of 1988, but after that, it will require fifteen years to return to a favorable opposition.

Mars's path through the stars from April through October and its brightness changes are shown in the illustration. You should have no difficulty finding the planet in June; it will be the brightest object in the night sky, rising in the east before midnight and setting in the west at dawn.

The loop Mars follows this summer is the apparent retrograde (westerly) motion that results whenever the earth, moving around the sun faster than Mars does, passes between the planet and the sun in our sky. The effect of our passing the planet causes its easterly movement to reverse direction in June. The planet then seems to back up among the stars until August, when it again reverses to its true, easterly direction and moves on toward Capricornus. At opposition, Mars and th earth are nearest one another.

Not all oppositions are equal, however the earth and Mars move in elliptical, no circular, orbits, and Mars's is by far th more eccentric. When they pass one an other, the distance separating them ca range from 35 million miles to about 6 million miles. Mars's perihelion (where it i nearest the sun) is located very close to th direction of Sagittarius, and the earth is i that part of the solar system in late sum mer. Oppositions of Mars (when the eart passes it) occur about every twenty-si months, but only every fifteen or seventee years do they occur near Sagittarius. Whe that happens this year, we will have the bes show Mars will put on in thirty years.

All through the period from April t October, Mars will be brighter than an star in our sky but Sirius. For a time i July, Mars will even rival Jupiter in bright ness. The best viewing of all will be i August, when brilliant Venus, reddish Mars, and bright Jupiter are all in the sky together during the early evening.

Celestial Events

June 17: After passing Spica during the ıy, the moon paces slowly away from the ar (to the left) while both creep westerly ross the sky.

June 19–20: Saturn is above and to the oon's left on the 19th, to its right on the)th. The reddish star nearer and below e moon on the 20th is Antares in Scor- us. North and Central Asia are hosts to ı occultation of Antares when the moon vers it at about 2:00 A.M., EST, on the)th.

June 21: The beginning of summer is iggered in the Northern Hemisphere at 1:30 A.M., EST, when the sun arrives at ıe summer solstice in Gemini. Perigee ıoon (nearest the earth) and full moon (at 0:42 P.M., EST) also occur, raising peri- ee spring tides tonight and tomorrow. he two reddish objects that bracket the ıoon after dark are Mars (the brighter) nd Antares.

June 22–23: Mars and the moon domi- ate on both nights when the sky darkens, ighlighting the constellation Sagittarius. he just-past-full moon is bright enough to ide most of the Archer's stars in its scat- ered light, but nearby Mars should be asily seen.

June 24: A string of stars above the ıoon and a V connecting its ends outline ıe "bikini" that identifies Capricornus.

June 25: Mercury's greatest easterly longation locates it favorably as an eve- ing star. Look low in the west after sun- own for a week or so before and after oday; the planet will be brighter on the arlier dates.

June 27–28: Jupiter and the moon rise ogether after midnight, near the border f Aquarius with Pisces.

June 28–29: Last-quarter moon is at :53 P.M., EST, but the moon rises after nidnight in Pisces, near Cetus's border, nd remains in the sky past dawn. The Whale's brightest star is Diphda, south of he moon.

June 30: The crescent moon rises in the norning about an hour past midnight in Aries, beneath the Ram's brightest stars, Hamal and Sheratan.

Editor's Note: The Sky Map in the April ssue shows the evening constellations and tars for this month and gives the dates nd times for use.

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The Mountains Come to Manhattan

A taste of Tibetan life can now be sampled closer to home

by Raymond Sokolov

At an earlier point in his career, the now all-powerful executive editor of the *New York Times*, A.M. Rosenthal, gained glory as the paper's United Nations correspondent. The U.N. had been a good story for him and it could be a good one for me, he advised, as the General Assembly reconvened once again in the early seventies. Mr. Rosenthal's notion was that I should interview some of the delegates and ask them what they thought of the food of their countries as it was served in New York.

The suggestion bore fruit, but not of the sort expected. Rosenthal, as I recall, hoped that their Excellencies would offer informed tips on restaurants and shopping. In fact, they provided unintentional insights into what might be called their national characters. The French ambassador complained that fresh sardines were unavailable here (a false claim) and greatly missed *sardines grillées*. The Japanese ambassador, on the other hand, was perhaps overly eager to be a good guest in our city. He pronounced himself enraptured by the food at a local Japanese restaurant that no serious person believed was more than passable. And he declared that our Atlantic tuna was considered superior for sashimi even in Japan.

The Mongolian ambassador did not return my calls. This was not a great blow to me, since there are no Mongolian restaurants in New York. I had hoped merely to elicit confirmation of this and to find out how the man was adjusting to a diet of exotic American dishes unredeemed by easy access to fermented mare's milk. It had also seemed possible that he would want to fulminate against non-Asian, capitalist steak tartare, but he did not rise to the bait.

Searching for someone to take his place as odd man out, I called the newly created mission of the kingdom of Bhutan. The staff had dived happily into New York gastronomic life. Cut off utterly from their Himalayan culture, they had discovered American steak. One of them had the menu of a well-known steakhouse in his desk. Did it remind him of yak meat, I asked? He dodged the question but admitted to having taken a nostalgic pilgrimage to the yak cage in the Central Park Zoo. Much has changed in Gotham since then. The yaks are gone from the park. But food of the Himalayas is now routinely available at Tibetan Kitchen, a popular little place on Third Avenue near Gramercy Park. The mountains have, as it were, come to Manhattan.

Well, not entirely. The restaurant serves no yak products and also does not make the effort to prepare *tsampa,* the main staple of Tibet. Usually made from barley, *tsampa* is a flour ground from toasted grain. Tibetans sometimes use wheat, corn, millet, oats, and soybeans. common traditional method for toasting to mix the whole grain with sand in a la pan and stir over a fire with a special lit broom made for the purpose. This p vents burning. The resultant toast whole grain, called *yoe,* is extracted fr the sand with a sifter. It is sometim eaten, as is, for a snack. To convert *y* into *tsampa*, villagers grind it by ha with a simple stone mill of the type kno in English as a quern. The fine, nut flavored flour is the subject of a sm cuisine of its own. *Tsampa* can be spr kled into water or tea or eaten plain. The is *tsampa* soup and *tsampa* cake.

I learned all this in Rinjing Dorje's formative new book, *Food in Tibetan L* (London: Prospect Books, distributed he by the University Press of Virginia, B 3608, University Station, Charlottesvil VA 22903). Dorje now lives in Seattle (at least, was living there in 1984, the

Galen Ro

Tibetans gathered for a meal that includes fried tsampa

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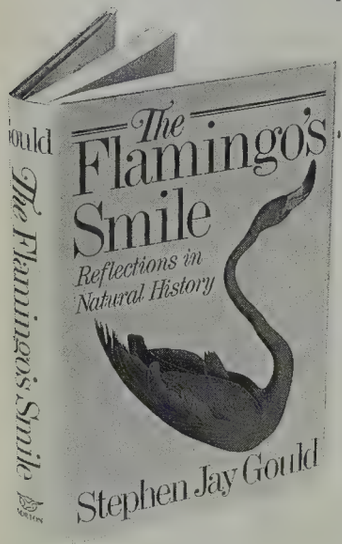

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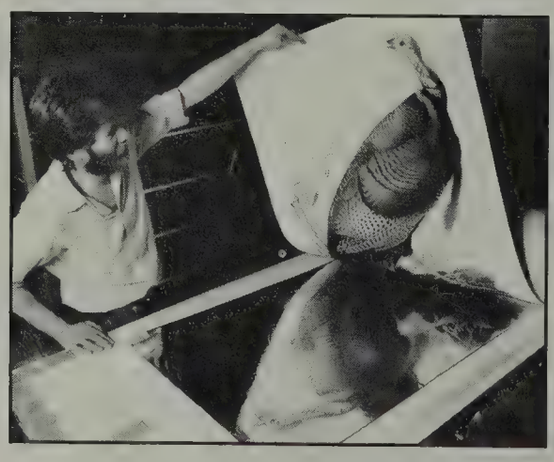

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betan year of the wood mouse, when signed the acknowledgment section to book). He was born in a Tibetan vill and once worked as a cook in a Budd monastery.

Although it contains many recip clearly written and mostly practical make in this country, *Food in Tibetan* is really a portrait of a culture s through its food and food customs. D cated to the exiled Dalai Lama, and proved by his "Office," the book is als political work.

In his preface, Dorje writes:

> Our unique and centuries old culture is carried on by only a small number of Ti ans, outside the country, under the gu ance of His Holiness the Dalai Lama. Si the invasion of Tibet by the People's public of China in 1950 this culture been in danger of being lost to the wo But, even though many of the best part our way of life have been destroyed in homeland, some of us continue to pract and enjoy them in exile. I hope that th who read this book will also gain from some "taste" and appreciation for the t Tibetan lifestyle.

Do not be misled by this into think that Dorje has written a somber, pond ous book. His approach is gentle and lig hearted. Much of this grace seems spring from the spirit of rural traditio Tibetan life, which he describes with l and good humor—as in the recipe *tsampa* cake, or *pag.*

The actual "cooking" is simple to scribe: one adds butter, ground chee and sugar to tea. *Tsampa* is kneaded i this doughy mass, which is then shap into an inch-thick square. But there more. There is a way to make little *p* balls in a teacup or even while hiking the Himalayas:

> Sometimes travelers carry a small leath bag called *pulkhug* or *thangug.* To prep *pag* they put all the ingredients in this b tie up the mouth and then rub it gently they are walking along. This way they c mix their *pag* without stopping. But there a secret to making *pag* in this way. T *tsampa* must go into the bag first. If the and butter go in first, the bag will get w and everything will stick to it. Then you w have a mess, not *pag.*

This all makes me eager to try *pag.* I suppose that I hadn't read this elegan simple bit of ethnography and that r local Tibetan restaurant prepared it, wi or without benefit of *pulkhug* or *thangu* Would I like it as well if I were not vicarious possession of a cultural conte for appreciating it? I don't think so. Ob ously, no one without real experience Tibet could possibly bring the sa

ealth of associations to this or other *ampa* preparations that a person could ho had tasted them *in situ*. But Dorje as helped us all to bridge that gap, in uch the same way that he might explain is odd-seeming food to an American uest in his house.

Unfortunately, the amiable staff at Tietan Kitchen cannot hope that very any of their customers will have read orje or will bring any prior experience ith Tibetan food with them into the resurant. And I imagine that it is caution bout serving something as exotic as *pag r tsampa* tea to Americans that keeps em from risking it on their menu. The aitress told us that making *tsampa* was o much work, but I speculate that the eal motive was commercial timidity, not aziness. After all, they do go to the trouble of assembling two kinds of *momo*. *Momo* closely resemble the little stuffed umplings so common in Chinese restauants. No doubt they were originally rought to Tibet from China. And it may ell be that Tibetan Kitchen calculated hat their clientele would readily accept *momo* because they had already encountered this kind of dumpling elsewhere. Indeed, much of the restaurant's menu is aken up with dishes close to Chinese or ndian dishes—bean curd, "curry," and arious stir-fried concoctions.

I want to stress that the quality of the ood at Tibetan Kitchen was high and did ot suffer when compared with its Chiese or Indian analogues. But if I had not ead *Food in Tibetan Life* before I ate Tibetan Kitchen's food, it would have eemed less interesting, and I would inevtably have taken it as loan-food borrowed rom more major cultures. But I knew etter. I knew that Tibetans had put *momo* at the center of their cuisine, that hey had made them their own.

Dorje tells us that in Tibet *momo* are olded into many different shapes to fit pecial occasions, that they are sometimes made with a tiny hole at the top so that juice can be sucked out before the dumpling is put in the mouth, and that garrulous Tibetans are told to keep their mouths shut "like a *momo*." Dumplings are crucial, he explains, to the soup called *gutuk*, which is served in ceremonial preparation for the new year. Some of the dumplings in *gutuk* are large and stuffed with surprises. Each member of the family gets one and opens it like a fortune cookie. Some contain written messages, but the most traditional have humorous symbols in them. Wool means the person is lazy; coal means he is malicious; sheep pellets stand for cleverness.

"*Gutuk*," says Dorje,

means ninth soup .... There must be at least nine ingredients in the soup, and each person must eat at least nine bowls. Everyone will insist on this, and so some clever guests bring their own small bowls along. Everyone saves a little at the end and then dumps this into a large wok. They each cut off a piece of hair, a piece of fingernail, and a piece of old clothing. These are put into the wok too. Then they clean the chimney and put the dirt in the wok. Finally they make an effigy of a person out of dough and set it in the center of the pile in the wok.

Children take this antifood, set it down at a crossroads and make as much noise as they can to scare away the waning year's negative forces.

Some reports indicate that a change in Chinese policy toward Tibet is now allowing this ancient way of life to reestablish itself. Let us hope so. But in the meantime, it is worth reflecting on how a cultural context—even just the knowledge that one did or does exist—can change our perception of food. This is not a sophisticated concept. It lies at the heart of our appreciation of what we eat.

Raymond Sokolov is a writer whose special interests are the history and preparation of food.

Shogok Katsa

(Tibetan hot potato curry, slightly adapted from *Food in Tibetan Life*, by Rinjing Dorje)

- 4 pounds potatoes
- ½ cup chopped tomatoes
- 1 teaspoon hot chili
- 2 cloves garlic, crushed
- ½ teaspoon grated ginger
- ¼ teaspoon turmeric
- Salt
- 1 medium shallot, chopped
- 2 tablespoons olive or vegetable oil
- ½ teaspoon fenugreek seeds
- ½ cup thinly sliced bell pepper

1. Boil the potatoes until they are cooked, then peel and dice them.
2. In a blender, put everything except potatoes, oil, fenugreek, and sliced pepper. Blend until everything is mashed.
3. Heat the oil and brown the fenugreek seeds, then add the mixture from the blender. Stir well and cook over high heat for one minute.
4. Pour the mixture over the potatoes and mix gently until well blended. Then garnish with the slices of bell pepper.

Yield 4 to 5 servings

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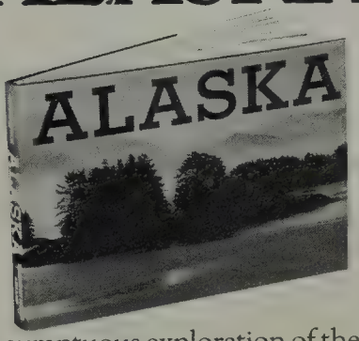

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At the American Museum

Modern Biological Theories of Aging

A major symposium on the biology of aging, will take place from June 3 through June 6. The daytime sessions, for professionals, will be held at Mount Sinai Medical Center; topics include free radical damage, error catastrophe, DNA damage and repair, and the evolution of life span and organ systems as pacemakers of aging. The fee is $200 ($25 for students with ID). On June 3, 4, and 5 at 8:00 P.M., public lectures will take place in the Museum's Main Auditorium. These talks are free with Museum admission. The scheduled speakers are Sherwood Washburn, Edward Schneider, and W. Ted Brown. For information call (212) 650-6737.

Elements of African Religions in the New World

Santería, the Yoruba-based religion of Cuba, and Candomblé, an African-based Brazilian cult, are the subjects of a free lecture program that will include films and slides. This program will take place in the Kaufmann Theater on Thursday, June 5, at 7:00 P.M. For additional information call (212) 873-1300, ext. 514.

On Saturday, June 7, at 2:00 and 4:00 P.M., the Museum will present *Patakin,* a program of authentic Santería music and dance. Also included will be songs and dances from the Abakua, an all-male society that originated in Africa. Free tickets will be available at the Kaufmann Theater ticket booth starting at noon on the day of the performance. For additional information call (212) 873-1300, ext. 514.

Lost and Found Traditions

Textiles, pottery, baskets, jewelry, a carvings are among the items in the fi comprehensive exhibition stressing t survival of Native American art for into the present. The works on display clude a Pima tray basket woven in a bee design, a lavishly decorated war shirt, a a thirty-five-foot-high totem pole from t Nishga branch of the Tsimshian peopl of British Columbia. All works in the ex bition were obtained directly from t American Indian community. *Lost a Found Traditions: Native American A 1965-1985* opens Friday, June 6, in G lery 1, where it can be viewed throu October 5.

Wolves and Humans

During the thousands of years th wolves and humans have coexisted, tal myths, beliefs, and works of art have ho ored—and attacked—this familiar cani *Wolves and Humans: Coexistence, Co petition, and Conflict,* opening in Galle 3, on June 11, explores both the folklo and biology of the wolf. The exhibition i cludes wolf masks, a videotape on t pack behavior of wolves, a comput wolf–prey game, twelve taxidermical prepared wolves surrounding a recent ki comparisons of wolf and human huntin behavior, a "flip-book" of wolf legend and many other innovative displays. T exhibition will be on view through Mo day, September 1.

In conjunction with the opening *Wolves and Humans,* a special showing

The gray wolf Scot Stew

film *Never Cry Wolf* will be presented Saturday, June 21, at 2:00 P.M. in the ıfmann Theater. Directed by Carroll lard, the film is a true account of biolo- Farley Mowat's study of the arctic f. The program is free and seating is on rst-come, first-served basis. For addi- ıal information call (212) 873-1300, . 559.

e Great White Whale

The 1956 film classic *Moby Dick,* star- g Gregory Peck and Richard Basehart, l be shown in the Kaufmann Theater Tuesday, June 10, at 1:00 P.M. Dr. eve Cumbaa of the National Museum Natural History in Ottawa will intro- ce the film, and discuss the facts and fa- s of whales and whaling. Seating for s free program is on a first-come, first- ved basis. For additional information l (212) 873-1300, ext. 559.

e Earth Is Our First Teacher

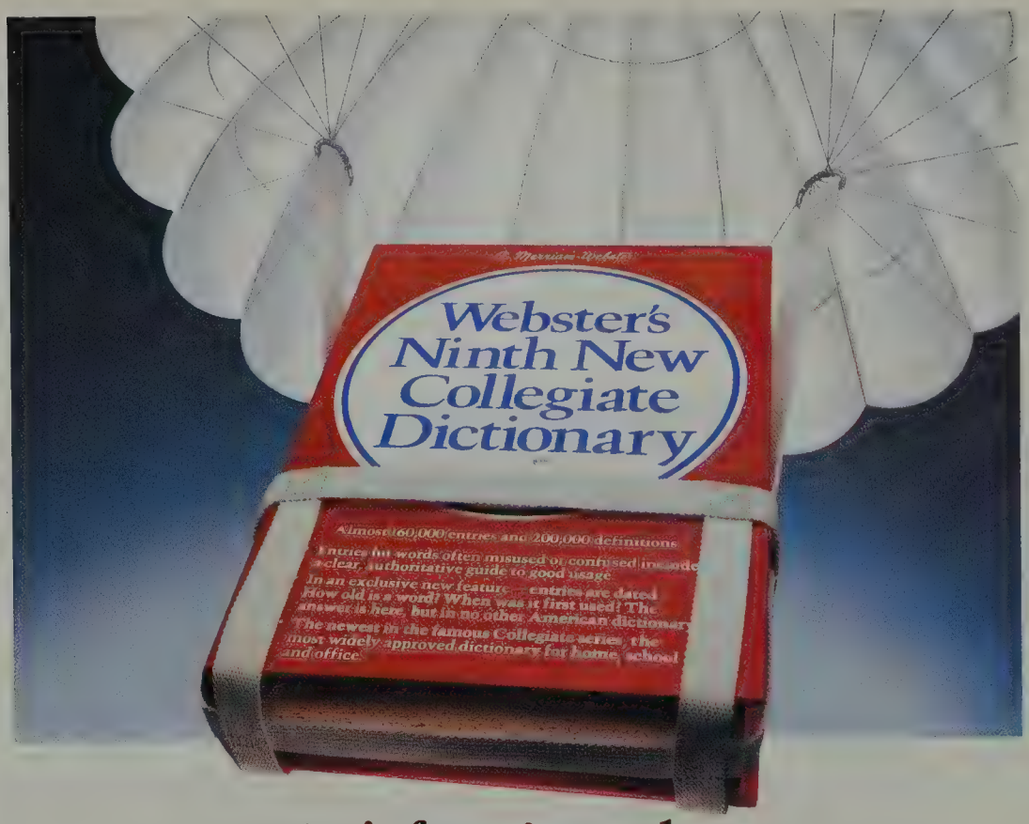
From the Puget Sound region that is me to the Salish Indians, come creation ths and stories of the Northwest moun- ns, forests, and salt water that show the credness of the world in ancient times d now. On Thursday, June 26, at 7:30 M., storyteller Rebecca Chamberlain, companied by a Northwest Coast elder, ll share the images, humor, and wisdom Salish folklore in the Kaufmann The- er. Tickets are $5.00 for members, .00 for nonmembers. For additional in- rmation call (212) 873-1327.

entification Day

Museum scientists from several differ- t departments will be on hand Satur- y, June 14, to help Museum visitors entify objects found anywhere from the p of a high mountain in an exotic land to neighborhood junk heap. *ID Day* will ke place from 1:00 to 5:00 P.M. in the ana Education Wing, first floor. For ad- tional information about this free pro- am call (212) 873-1300, ext. 559.

t the Hayden Planetarium

The Planetarium's Laser Light Shows ave made a recent comeback with the rand-new *Laser Beatles*. Among the any Beatle songs featured in the show re "Lucy in the Sky With Diamonds," Octopus Garden," "While My Guitar ently Weeps," and "Yesterday." Tick- ts can be ordered in advance through icketron or purchased on the evening of he performance at the Planetarium Box ffice. *Laser Beatles* takes place on Fri- ay and Saturday nights at 7:00, 8:30, and 0:30. For ticket prices and additional in- ormation call (212) 724-8700. Members eceive a discount.



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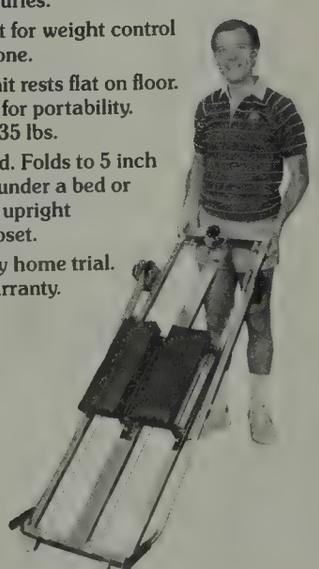

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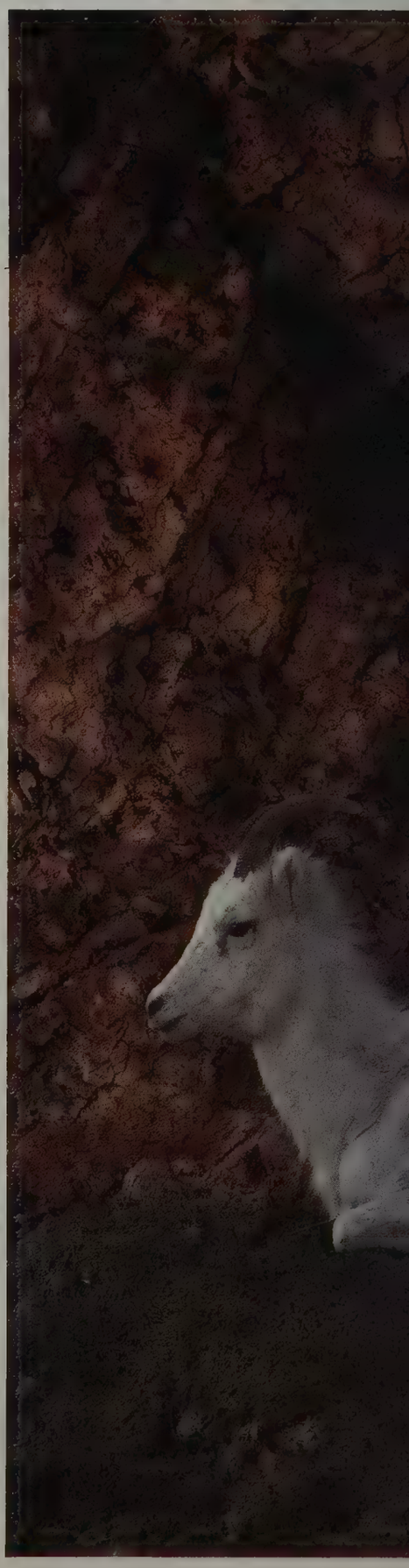
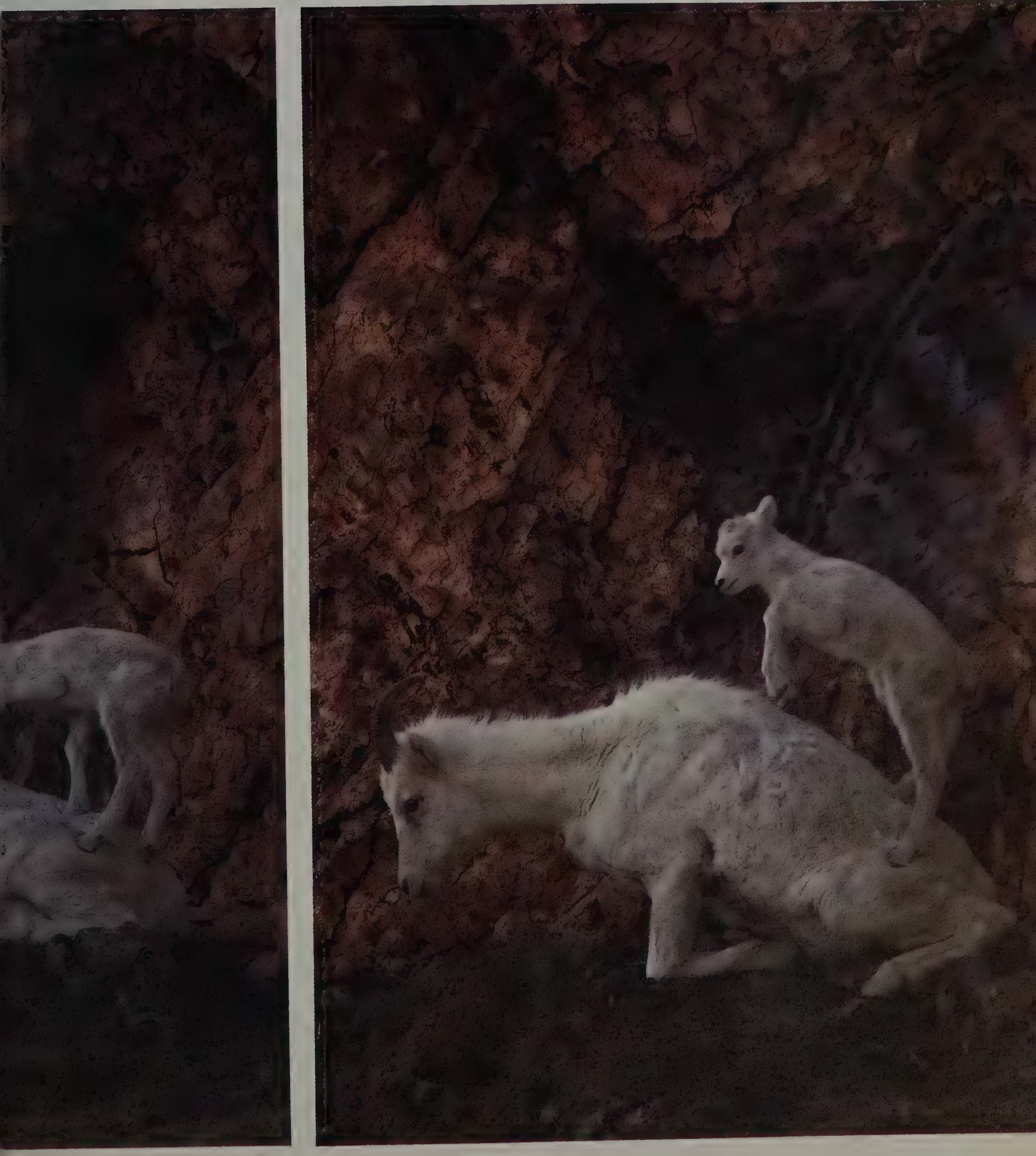


Photographs by Martin W. Grosnick



Although you can't see it in this telephoto view, this Dall's sheep moth and lamb are on a ledge about halfwa a 4,000-foot cliff in Alaska's southern wilderness. A close relative—some zoologists think a subspecies—of big sheep, Dall's sheep are found in most Alaska, the Yukon, and northern Brit Columbia. They are distinguished by long, slender horns, not so tightly curl those of the bighorn, and their white o black coats, which are not wool but a dense, coarse hair. Flocks of up to one hundred sheep have been observed in sharply angled foothills of the Alaska Range.

Mating takes place very late in autu after rutting rituals during which ram butt heads over rights to females, and lambing occurs in May, at the beginni of the northern spring. Dall's sheep ar usually gregarious, but in preparation birth, a ewe moves away from the othe sheep, probably to insure that her newborn becomes imprinted on her al

An expectant ewe picks a sheltered spot, usually on a cliff ledge. An hour o two after birth, the lamb can move aro on its own. It spends the first week of li on the ledge, nursing about one minut a time, often more than once an hour. T ewe remains on guard.

As photographer Martin Grosnick observed, a lamb, like the young of mammals everywhere, can be very persuasive when it is hungry. This lam got its mother's attention by prancing her back with its tiny hoofs. Finally, th ewe reluctantly stood up and the lamb nuzzled in.

In a few more weeks the lamb, no lo small enough to pass easily under its mother, will have to kneel to feed. By t mother and young will have joined a flo of ewes and lambs wandering the mountain in search of food. Even when is getting most of its nourishment from grazing on grasses, dwarf willow, and wildflowers, the lamb may continue to nurse into its first winter. This means th ewe, like mothers everywhere, will get little time to rest and ruminate.

Charles C. M

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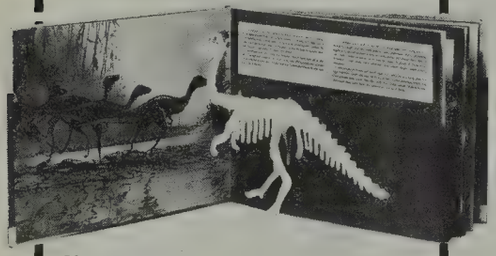

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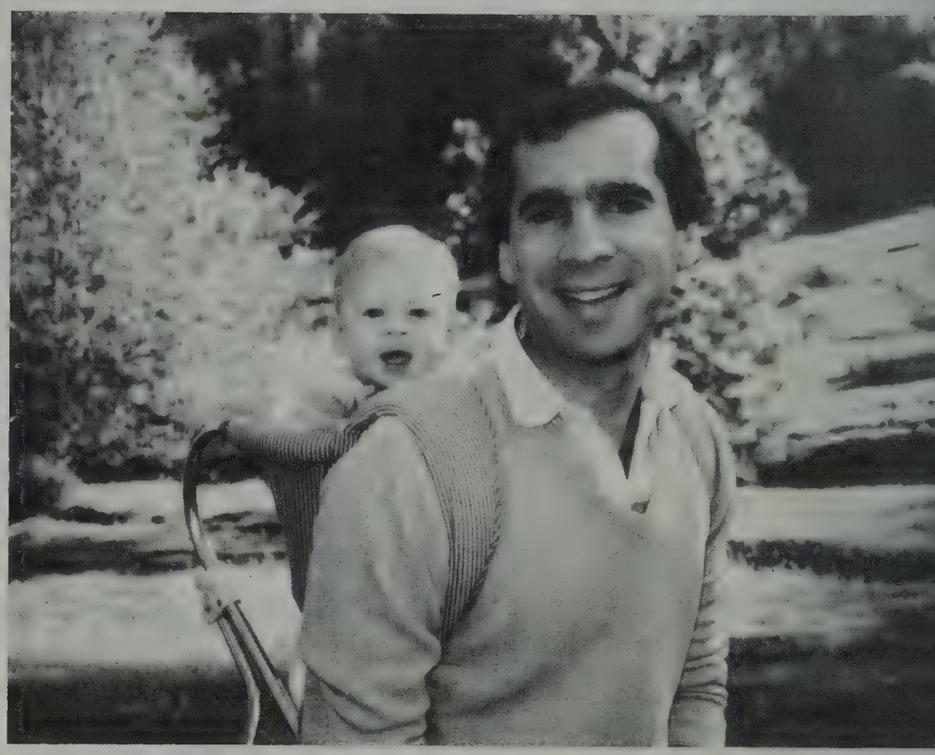
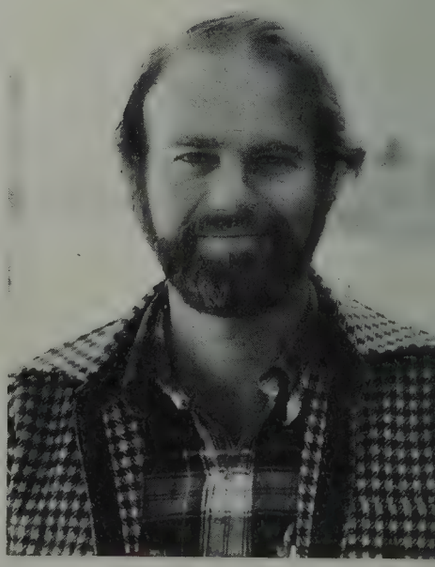
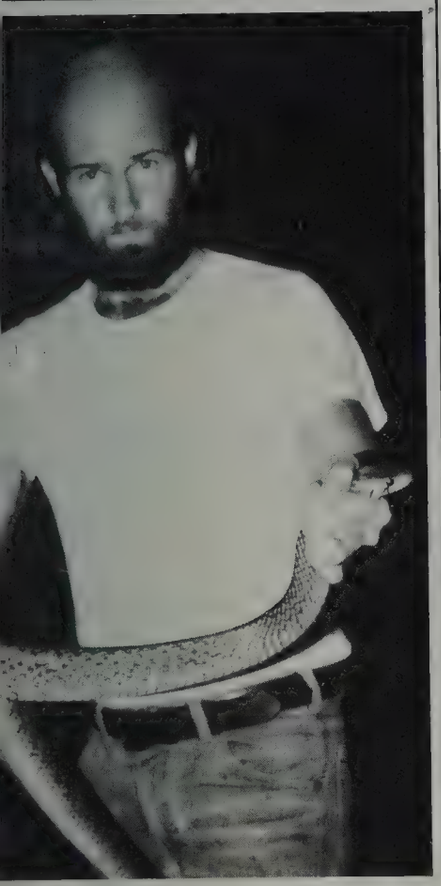


Ross S. Stein (page 28) first learned of the Borah Peak earthquake when he read about it in a newspaper while vacationing in Hawaii. "An earthquake is an experiment that cannot be planned," he observed, so he rushed to Idaho to study it. A geophysicist at the Office of Earthquakes, Volcanoes, and Engineering of the U.S. Geological Survey, Stein specializes in the study of earthquake mechanics and prediction. He has done fieldwork on faults in California, Montana, Nevada, the Aleutian Islands, and Corinth and Thessaloniki in Greece. He is now planning a joint research project with the Bulgarian Academy of Sciences to investigate the site of a 1928 earthquake in Bulgaria. For readers who would like to learn more about the geology involved in these phenomena he suggests *Basin and Range,* by John McPhee (New York: Farrar, Straus, & Giroux, Inc., 1981) available in paperback and meant for the general reader. Coauthor **Robert C. Bucknam** is a geological engineer who also works for the U.S. Geological Survey. His specialty is the "study of the nature of surface faulting produced by large earthquakes with emphasis on the development of methods of dating the scarps produced by pre toric earthquakes." He adds: "I wa Salt Lake City when the [1983] qu occurred and felt the shaking. I flew the area of the earthquake later that and could see the opportunity offere the spectacular faulting."





For **Michael J. Ryan** (page 36), his ly interest in animal behavior and tiles and amphibians converged in his ster's thesis on the mating behavior of lfrogs. The striking differences he ed in the mating call of male frogs led n to ask how variation in courtship dis- ys within a species influences female oice of mates. An assistant professor zoology at the University of Texas and esearch associate at the Smithsonian opical Research Institute, Ryan con- cted his fieldwork in Panama between 78 and 1981. The results of his re- arch are detailed in his recent book, *e Túngara Frog: A Study in Sexual lection and Communication* (Chi- go: University of Chicago Press, 85). For those who want information other aspects of frog biology, Ryan ggests *The Frog Book,* by M.C. ckerson (New York: Dover Publica- ns, Inc., 1969). When the whistles, rps, and whines of the frogs prove in- fficient music to his ears, Ryan relaxes the strains of rock-and-roll.

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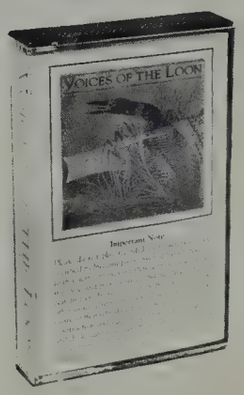

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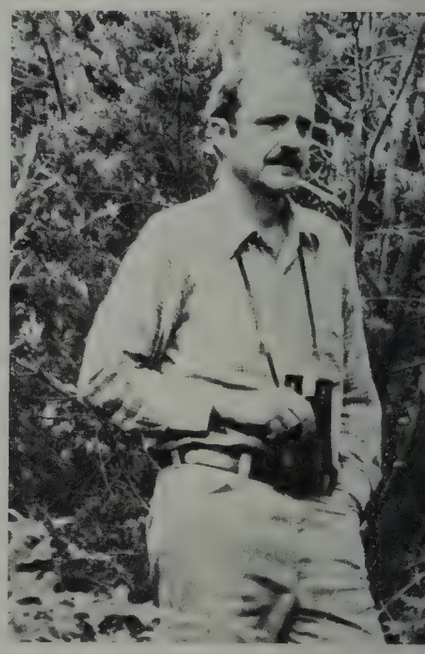
The National Park Service has administered the Custer Battlefield National Monument as a memorial and tourist attraction for years, but the site's archeological potential was neglected until 1983, when a wildfire burned off the vegetation. After the fire, **Douglas D. Scott,** coauthor **Melissa A. Connor** (page 46) and others undertook a scientific reappraisal of Custer's Last Stand. Scott (above) is chief of the Rocky Mountain division of the National Park Service's Midwest Archeological Center at Lincoln, Nebraska. He was chosen to coordinate the Service's involvement in the project because of his previous experience in the archeology of historic military sites. In 1984, when the first field season got under way, Scott and the other participating archeologists were so swamped by volunteers and the news media that Scott added Connor (below) to the team. A senior research archeologist in the Department of Anthropology at the University of Nebraska in Lincoln, Connor later took charge of the 1985 excavations. She says she has not become a Custer buff, but is intrigued by doing archeology at a site created in about an hour—instead of over millennia. For those who cannot resist becoming Custer buffs, Scott recommends reading John S. Gray's *Centennial Campaign* (Fort Collins, Colorado: The Old Army Press, 1976) and W.A. Graham's *The Custer Myth* (New York: Bonanza Books, 1953).

Ten years ago, **Martin W. Grosnick** (page 82), who photographed this month's "Natural Moment," moved from Michigan to Alaska—that is, he says, "from where it's cold to where it's really cold." After setting up shop in a superinsulated cabin outside Denali National Park, he began photographing "all the large mammals, including sheep, moose, bear, and caribou." According to Grosnick, "sheep are the safest animals I shoot—except for the long climb to find them." For this shot, taken with a Nikon and a 400-mm telephoto lens, he first had to scramble up a 1,000-foot-high, rock-strewn slope that was prime leg-breaking territory, then wait for half an hour until the startled ewe calmed down and tried—unsuccessfully, as it turned out—to take a nap.



As a ten-year-old on his way to a ball game, **Frederick R. Gehlbach** (p 56) spotted four young screech ow an oak tree and knocked them off, on one, with his softball, examined th and put them back on a low limb. next day they were gone (perhaps surprisingly), but Gehlbach could put them out of his mind. His intere owls and other birds of prey grew in life's work. Gehlbach is now professo biology and environmental studie Baylor University in Waco, Texas, for the past two decades, the focus o research has been the biology and servation of urban and suburban mals, the screech owl in particular. has also done broad ecological studie the Southwest and Mexico. Years sp investigating the animals and pl along the U.S.–Mexico border resu in a book, *Mountain Islands and De Seas: A Natural History of the U.S Mexican Borderlands* (College Stat Texas A & M University Press, 19 For readers wishing to learn more ab owls, he recommends *Owls: Their Na ral and Unnatural History,* by J Sparks and Tony Soper (New Y Taplinger Publishing Co., 1979) John A. Burton's *Owls of the Wo Their Evolution, Structure, and E ogy* (Dover: Tanager Books, 1985).

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Vol. 95, No. 7, July 1986
American Museum of Natural History, New York, N.Y.
Robert G. Goelet, President
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4 Letters

6 Fat Tooth Blues *S. Boyd Eaton and Marjorie Shostak*
Our Stone Age ancestors had a lean cuisine.

16 This View of Life *Stephen Jay Gould*
The Egg-a-Day Barrier

26 A Naturalist at Large *Lester L. Short and Jennifer F.M. Horne*
The Ivorybill Still Lives

30 This Land *Robert H. Mohlenbrock*
Bradshaw Mountains, Arizona

34 In the Realm of the Buddha *Frits Staal, photographs by Adelaide de Menil*
Only a few Westerners have seen the priceless wall paintings of Tsaparang, an ancient citadel on a barren plateau in western Tibet.

46 Pussy Cat, Pussy Cat, Where Have You Been? *Andrew T. Lloyd*
When settlers came to the New World, they brought their cats with them.

54 On the Dilemma of Horns *Luther Brown and Larry L. Rockwood, paintings by Bernard Durin*
Why do the picturesque horned beetles grow such large appendages?

62 The Acid Rain Whodunit *Kenneth A. Rahn and Douglas H. Lowenthal*
Careful scientific detective work has solved an environmental mystery.

66 Reviews *Matt Cartmill*
Animal Rights and Wrongs

70 Celestial Events *Thomas D. Nicholson*
The Planet Chase

74 The Living Museum *Laurie Nadel*
Lost and Found Traditions

80 A Matter of Taste *Raymond Sokolov*
Addressing Salad

88 The Natural Moment *Photograph by Dave Woodward*
School Bully

90 Authors

Cover: *Yama, Hindu god of death, guards the entrance to the Tantric temple at Tsaparang in western Tibet. A recent exploration of the now abandoned Buddhist bastion found its tenth-century murals remarkably well preserved. Photograph by Adelaide de Menil. Story on page 34.*

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Sheep and Scientists, Wolves and Theologians

In the last paragraph of Stephen Jay Gould's otherwise wonderful column "Knight Takes Bishop"?("This View of Life," May 1986), in which he declares that there is no battle between religion and science, he falls, unfortunately, into the trap of ethnocentrism by generalizing from his own liberal, eclectic position on matters religious to all organized religion. Certainly, science has no quarrel with religious emotions, but this is not true the other way around: a sheep could live with a wolf, but a wolf cannot be expected t peacefully coexist with a sheep. The inne logic of religion, especially revelation rel gion, strives relentlessly toward tota domination of all aspects of life, includin ethics, politics, and science. The "ques tioning theologian" Gould piously lauds, i a contradiction in terms. If it had not bee for Huxley and the many people like hir before and after his time, Gould woul now recite the creation myth in an inqu sition dungeon in much the same way a his counterparts are forced to do in Iran where religious thinking has achieved nearly pure form of reification.

REINHOLD LOEFFLE
Western Michigan Universit
Kalamazoo, Michiga

Bishop Wilberforce is no favorite c mine, but I found Stephen Jay Gould article a wonder of reexamination in th interests of historical justice. More wo derful still was his suggestion that inqui ing scientists need to join hands with que tioning theologians in order to preserv "that most fragile of all needs, Libert itself." I do hope that this view will hav its wanted impact and help to open u increased possibilities for useful dialogu between scientists and theologians.

JAMES A. CARPENTE
The General Theological Seminar
New York, New Yor

Gould decries the kind of artificial div sion and polarization that has come to b between religion and science. As a scie tist (if a country veterinarian can be calle one) and a Christian, I have been sa dened by that division, which separat many people from each other and fro important knowledge. I fervently hop that Stephen Jay Gould's message falls c receptive ears.

JOE SNYDE
Myrtle Point, Orego

THE MARSUPIAL TRAIL

Joe LeMonnier

Clarification: *The yellow-colored areas on the map, "The Marsupial Trail" (May 1986, page 63), show the known distribution of marsupials 65 million years ago, at the end of the Cretaceous period. Fossil finds indicate that during the 40 million years after the end of the Cretaceous, marsupials reached western Europe, North Africa, and Central Asia.*

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Fat Tooth Blues

Our diet has deviated dangerously from that of our Stone Age ancestors

by S. Boyd Eaton and Marjorie Shostak

A taste for fat, like that for sugar, seems to be part of our human makeup, probably because our primate ancestors ate foods containing these nutrients over tens of millions of years. Fruits, rich in sugar, have been a dietary staple for at least the last twenty-five million years of our evolution, and fat is found in both nuts and meat, items popular with baboons, chimpanzees, and other primates whose omnivorous nature reflects that of our more immediate prehuman ancestors.

While fat may have been a taste marker for foods our antecedents relished, under natural circumstances their diet provided fat in relatively small amounts: nuts are typically seasonal and wild game is lean. Beginning in the nineteenth century, however, the food industry began to exploit our taste for fat. Selective breeding and altered feeding practices (including the "finishing" of cattle at feedlots with energy-concentrated corn and grain) have transformed the lean, stringy beef consumed by people in early agricultural societies into tender, juicy, well-marbled beef.

Fast-food chains have prospered on fried foods, which multiply the fat content of a base food item: fried shrimp have more than ten times the fat that boiled shrimp do and French fries have more than eighty times as much fat as do baked potatoes. Many basic foods are now incorporated into pastries, prepared mixes, snack foods, frozen dinners, and other composite items with a much higher fat content, or are garnished with such accompaniments as sour cream, salad dressing, and butter. Children now consume these high-fat foods from their earliest days, so that their tastes are shaped even more to favor and expect such food.

The good news is that fat is indispensable to our diets and to eliminate it completely would be harmful. Just as there are essential amino acids—those components of proteins that our bodies cannot synthesize from other dietary constituents—there are essential fatty acids. These are all polyunsaturated, that is, there are at least two double-bond links somewhere in the carbon-atom chain that makes up their backbones. These and similar, mostly polyunsaturated fats are necessary for formation of cell membranes and for synthesis of a variety of structural elements within cells. The body also uses them in the manufacture of prostaglandins, specialized hormones that regulate such things as blood pressure, blood clotting, and smooth muscle contraction.

The bad news is that—not even counting the extra calories—the kinds and amounts of fat we eat can hurt our health. There are two other kinds of fats, in addition to polyunsaturated fats. Monounsaturated fats contain one double-bond linkage in their carbon-chain backbones, and saturated fats contain no such double bonds. For many years scientists have known that polyunsaturated fats in the diet tend to lower blood cholesterol levels, though the underlying biochemical mechanism is not fully understood; very recent experimental evidence suggests that monounsaturated fats act similarly. Saturated fats, however, have the opposite effect of increasing the level of blood cholesterol. The higher the cholesterol level, the greater the risk of developing atherosclerosis (hardening of the arteries) and coronary heart disease.

Many experimental studies have shown that blood cholesterol levels are lowered in subjects who eat less fat and/or who increase their intake of polyunsaturated fat relative to saturated fat. Cross-cult studies also find far less coronary h disease among populations, such as Japanese and most Third World peo that consume little fat generally and to eat proportionately more polyuns rated fat than do Americans.

Total fat intake is also related to m cancers (polyunsaturated fats offer special protection in this regard). In c tries where relatively little fat is sumed, cancers of the breast, pros uterus, and colon are uncommon or rare. (Other dietary factors—such as fiber diets—may also be implicated, e cially in colon cancer.)

Fat intake seems related to cancer the breast, prostate, and uterus becau influences the levels of sex hormon estrogen in women and testosteron men. Migration studies show that va tion in the incidence of these can among groups cannot be explained by netic differences in susceptibility. For ample, ethnic Chinese women living Taiwan consume little fat, have relati low levels of estrogenic hormones, and perience little breast cancer; Chin American women living in Honolulu sume an intermediate amount of fat, h higher estrogen levels, and a mode amount of breast cancer; while Chin American women living in Boston ea much fat as do other Bostonians, h relatively high levels of estrogen, and h the same incidence of breast cancer a white American women. Similarly, b American men eat more fat, have hig testosterone levels, and develop more p tatic cancer than do black Nigerian m

Fat and cancer of the colon are rela through a different mechanism. An vated fat intake stimulates the live

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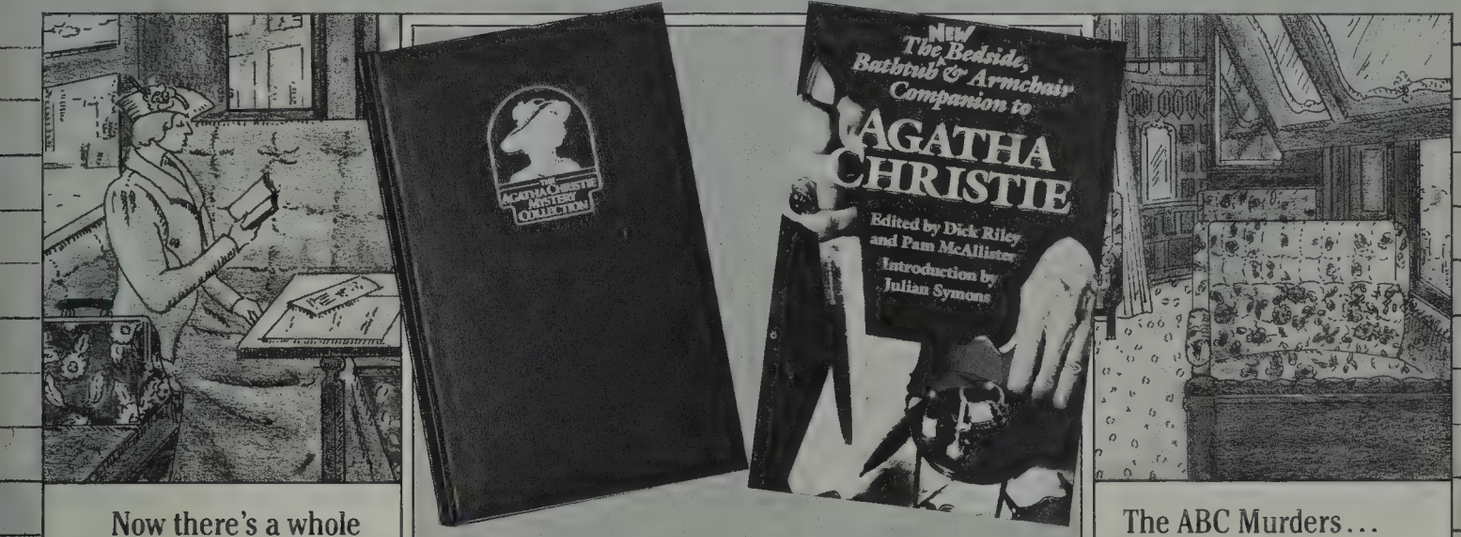
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secrete more bile, which aids in the absorption of fat. When bile acids pass from the liver into the intestinal tract, they are broken down by microorganisms into substances that are carcinogenic in laboratory animals. The Japanese diet has traditionally contained little fat and the incidence of colon cancer in that country has been very low. As Japan has become more affluent, however, the diet has come to include more fat, and the rate of colon cancer has increased substantially.

Compared with animal fat, vegetable fat is less likely to be saturated, and so is often recommended as more healthful. This difference was once less significant. The game our ancestors ate was much leaner than today's domesticated meat: a venison steak derives 82 percent of its calories from protein and 18 percent from fat, whereas a choice sirloin cut derives 84 percent of its calories from fat and only 16 percent from protein—proportions that are virtually reversed. Meat from free-ranging wild animals also has a much higher proportion of polyunsaturated fat (up to 50 percent) than does supermarket meat (5 percent or less).

Why should this be so? First, the vegetation consumed by game animals is higher in polyunsaturated fat than the artificial feed given cattle and pigs. Second, and more important, the excess fat in today's meat animals constitutes reserve energy stores, not structural elements. Structural fat present in both wild and domesticated animals is largely unsaturated. Storage, or depot, fat (found in layers under the skin, in the marbling of muscle tissue, and within the abdominal cavity) is overwhelmingly saturated. As concentrated sources of energy, these fatty deposits have survival value in times of food shortage. In nature, however, most animals are unable to accumulate anything like the amount of depot fat that our meat animals do as a result of their selective breeding, restricted physical activity, and unnatural diets. Before this century, even domesticated animals lacked the enormous saturated fat deposits we take for granted.

The health effects of the fats we eat are influenced by the other foods we consume and by our overall life style. These factors have also changed with time. Nevertheless, the difference between our diet and that of our hunter-gatherer forebears may hold keys to many of our current health problems. The hunting and gathering diet was eaten by all people on earth before the advent of agriculture 10,000 years ago. It was refined over hundreds of thousands—if not millions—of years, as we were evolving. So if there is a diet natural to human makeup, one to which our ge are still best suited, this is it.

A diet, now considered balanced cludes foods from four major grou meat, fish, and poultry; breads and ce als; fruits, nuts, and vegetables; and da products. People living before the dev opment of agriculture, however, had dairy foods at all (except mother's mi and until late in prehistory, made little no use of grains. Their entire diet v derived from wild game and uncultiva vegetables, and while the proportions these elements varied widely, we can s make a number of generalizations ab the nutrition of these people.

First, whether measured by weight by caloric contribution, plants were pr ably the staples of diet even before advent of agriculture, just as they ha been for most hunter-gatherers studied ethnographers. Although animal rema are better preserved in the paleontologi record, pollen analysis and the mic scopic study of husks, seeds, and oth plant remains provide some informat about the vegetables, fruits, and nuts c sumed. A great variety of plant foods w eaten; in some cases they were brought living sites from considerable distance

Second, the bulk of carbohydrates c

Douglas Mazonc

Lean cuisine: Middle Stone Age hunters target an ibex. This 8,000-year-old painting is in Remigia Cave in eastern Spain.

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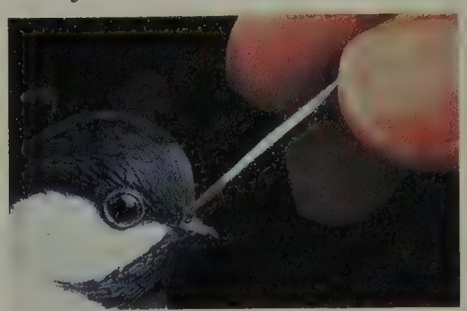

Painted by hand to reveal every detail of the chickadee's intricate markings.

Douglas Mazonowicz

A cave painting from Los Caballos, eastern Spain, depicts the ambush of a deer herd.

sumed in the past were complex, unlike the finely ground flours and refined sugars so abundant in our current diet. Early peoples obtained simple sugars from honey and fruit, but the general absence of dental caries in fossil teeth shows that they ate far fewer sweets than we do. Similarly, their intake of nonnutrient dietary fiber was greater.

Third, our forebears ate much more protein, especially animal protein, than we do (and because cholesterol is an integral part of all animal tissue, the amount of cholesterol they ate probably equaled or exceeded what we eat today). The Cro-Magnons, modern humans who lived in Europe between 35,000 and 10,000 years ago, possessed a hunting weaponry so advanced that they could systematically exploit the then plentiful herds of large game animals. The enormous numbers of animal bones found at kill sites and in living areas, as well as the preeminence of animal representations among ancient cave and rock wall paintings left by Cro-Magnons, indicate the importance of meat in their diet.

We can ascertain the relative proportions of animal and vegetable food consumed in the past by analyzing skeletal remains. Bones contain both strontium and calcium. Strontium is mostly found in plant foods, so that the bones of herbivores have a higher strontium/calcium ratio than do those of carnivores. Analysis of this ratio in human fossils shows that meat consumption declined just before and during the development of agriculture. Inspection of dental wear patterns, using the scanning electron microscope, tends to confirm this finding.

Finally, except for a deficiency of iodine in some geographical locations, our ancestors probably ate an abundance of vitamins and minerals (including calcium—even without any dairy foods. Their intake of potassium, as is the case for all other animals, exceeded their intake of sodium. For most Westernized people throughout the world, the reverse is now true.

Apart from diet, we can assess other features of the Stone Age life style. In isolated locations and in certain seasons some preagricultural people probably chewed tobacco—as do such modern-day hunters and gatherers as the Australian Aborigines. Tobacco was absent from most of the Old World, however, until the European discovery of America, and the New World was not populated until long after the appearance of anatomically modern humans about 40,000 years ago. Smoking almost certainly postdates the advent of agriculture 10,000 years ago, and cigarettes were not even developed until after the Crimean War, in the mid-1850s.

As for alcoholic beverages, if preagricultural people had any indigenous brews these were probably available only seasonally and produced by natural fermentation, not distillation. This would have resulted in drinks of relatively limited potency, beer, for example, as opposed to whiskey. Furthermore, studies of recent hunting and gathering peoples show that among them drinking is subject to strong conventions that limit the frequency and place of consumption, degree of permissible intoxication, and types of behavior that will be tolerated. In such circumstances, the solitary, addictive, pathological drinking found in Western societies is almost nonexistent.

Preagricultural hunter-gatherers were also physically fit throughout their lives. We can judge their physical strength directly because we have their skeletal remains. Elevations of dense bone develop where muscle tendons attach to bone. The size of these elevations reflects the forces generated by the muscles involved. When calibrated in this way, fossil remains show that our remote ancestors possessed great muscular strength, considerably more than is typical of today's Westerners.

Fossil bones show that ancestral peopl

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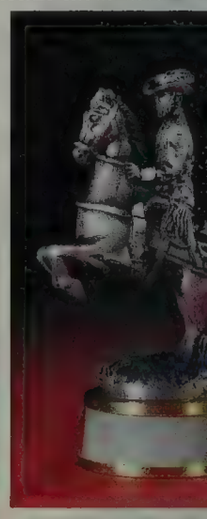

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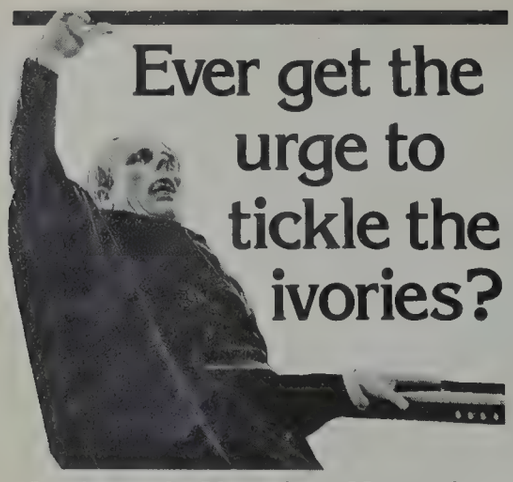

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were not only strong but also tall. The Cro-Magnons were slightly taller than present-day Americans. More impressive, the 1984 discovery of a nearly complete fossilized skeleton of *Homo erectus*—a more remote human ancestor—showed that people living as much as 1.6 million years ago were equal to us in height. The usual assumption has been that our ancestors were all smaller than we are.

These findings can be broadened by examining the life style of contemporary peoples who live by hunting and gathering, such as the !Kung and ≠Kade San (Bushmen) of Botswana, the Pygmies of Zaire, the Australian Aborigines, and the Arctic Eskimos. There are important differences between these people and our Stone Age ancestors. Contemporary hunters and gatherers inhabit ecologically marginal desert, jungle, or arctic regions where the food quest must be more difficult than it was for people living 25,000 years ago in richer locales. Most such groups are technologically more advanced than their Stone Age predecessors (even the ubiquitous bow and arrow is relatively new, appearing no earlier than 20,000 years ago), and virtually all have had considerable contact with the outside world. Nevertheless, many of the constraints operating on the hunting and gathering life in the past continue to shape this way of life today.

Studies of more than fifty such groups during this century reveal that their average (and most common) nutritional pattern is based on about 35 percent meat and 65 percent vegetable food, by weight. The range is considerable, from 90 percent meat in the Arctic to less than 15 percent in arid deserts. (The relative proportions in Western cultures are difficult to assess because so many of our foods are amalgamations of vegetable and animal products.)

Americans currently obtain between 40 and 45 percent of their daily calories from fat, and of this, twice as much is saturated as is polyunsaturated. Among hunter-gatherers, only about 20 percent of daily caloric intake is derived from fat, and of this, more is polyunsaturated than is saturated. (The Eskimos, an extreme case, traditionally obtained about 40 percent of their calories from fat, but this was high in polyunsaturated fat.) Cross-cultural differences were part of the evidence taken into account when the Senate Select Committee on Nutrition issued its Dietary Goals in 1978. These recommended that fat should provide 30 percent of American caloric needs, divided equally among saturated, monounsaturated, and polyunsaturated fat.

Aside from lower total fat intake a lower proportions of saturated to po unsaturated fat, hunter-gatherer diets flect other principles that American me cal organizations recommend: little s few refined sugars, high fiber, moder (although adequate) calories, and a w range of complex carbohydrates.

The hunting and gathering life st also involves considerable physical ex cise, begun in early childhood and cont ued throughout life. Much of this is hig aerobic, promoting stamina compara to that achieved in our society only accomplished endurance athletes. Care epidemiological investigations show t such aerobic fitness promotes health reducing blood pressure and by protect against atherosclerosis. Exertion in ta requiring physical strength, also typica hunter-gatherers, toughens bones and s porting tissues around joints, thus mi mizing the risk of osteoporosis and exc sive damage from trauma.

As a result of their life style, contem rary hunter-gatherers are healthier th we are, at least with regard to those "d eases of civilization"—heart attack, c cer, stroke, hypertension, obesity, and d betes—that cause most deaths in afflu Western nations. They do not suffer fr atherosclerosis, which predisposes us ward coronary heart disease. This is cause they are not exposed to cigarett eat relatively little fat (with a benefic ratio of polyunsaturated to saturated fa and generally maintain a high level aerobic fitness. A diet low in sodium containing ample potassium and calci keeps their blood pressures constant o the years (ours tend to rise with age), a they experience little or no hypertensi

Thanks to the strenuous physical act ity required by their lives and to a mod ate caloric intake (their foods aren't calo cally concentrated, as ours often ar hunter-gatherers are almost never ob and have exceptionally low rates of d betes. Unfortunately we know little abo cancer among foraging peoples, becau biopsy and autopsy data are generally available. Studies among the Eskim however, have found that the incidence cancer has increased significantly follo ing Westernization.

It is not because individuals in indus alized countries live longer that they a afflicted by the diseases of civilizati Young people in the Western world co monly harbor developing, asymptoma forms of these various conditions, where hunter-gatherer youth do not. Furth more, those members of foraging cultu who live to age sixty and beyond rem free from these diseases, in striking c

ast with persons of similar age who live Western nations.

This should not suggest that hunting-athering societies are, overall, healthier ian our own, because conditions we are ble to control (such as infections and auma) often cause the early death of eir members. But their life style does rotect hunter-gatherers from the diseases at kill most of us. By picking and choosing the best from their life style along with ie best from ours, we should be able to prestall (or even prevent) many currently rominent diseases and thus live longer, ealthier lives.

The diseases attributed by medical and pidemiological research to excessive dietary fat appear to represent chronic derangements of basic biological processes—metabolic pathways that evolution as conserved and that are functionally imilar to those of other mammals, of vertebrates generally, and even, in some ases, of unicellular organisms. These diseases differ completely from the infections and traumas that were the chief auses of death before this century.

The amount and type of fat we consume epresent new and exceptional metabolic ircumstances—ones that have previously hallenged few humans (or, for that matter, other animals). Our genes cannot have dapted in any significant way to this particular challenge. The glacial pace of genetic evolution is indicated by evidence hat the genes of humans and chimpanees differ by only about 1.5 percent, even hough our ancestors diverged from theirs bout seven million years ago. The novel ut widespread phenomenon of excessive at intake (and particularly our heavy load f saturated fat) is, over an entire life span, ncompatible with our genetically determined physiology and biochemistry. The esultant mismatch promotes diseases hat, taken together, cause more than half he deaths in the United States today.

. Boyd Eaton, M.D., is chief of radiology t West Paces Ferry Hospital in Atlanta, ssociate clinical professor of radiology t Emory University Medical School, and djunct associate professor of anthropology at Emory University. Marjorie Shostak, the author of Nisa: The Life nd Words of a !Kung Woman, *is research ssociate in anthropology at the Graduate Institute of Liberal Arts at Emory Jniversity. With coauthor Melvin Konner, Eaton and Shostak are writing a ook on the continuing importance of the unting and gathering adaptation to human life today. Tentatively titled* The Paeolithic Prescription, *it will be published n 1987 by Harper and Row.*

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The Egg-a-Day Barrier

Species evolve within limits set by persistent patterns of growth

by Stephen Jay Gould

In the opening sentence of *Hereditary Genius* (1869), the founding document of eugenics, Francis Galton (Charles Darwin's brilliant and eccentric cousin) proclaimed that "a man's natural abilities are derived by inheritance." He then added, making an appeal by analogy to changes induced by domestication:

> Consequently, as it is easy . . . to obtain by careful selection a permanent breed of dogs or horses gifted with peculiar powers of running, or of doing anything else, so it would be quite practicable to produce a highly-gifted race of men by judicious marriages during several consecutive generations.

Darwin had also invoked domestication as his first argument in the *Origin of Species*. Darwin began his great treatise, not with fanfare or general proclamation, but with a discussion of breeding in domestic pigeons:

> Believing that it is always best to study some special group, I have, after deliberation, taken up domestic pigeons . . . I have kept every breed which I could purchase or obtain . . . I have associated with several eminent fanciers, and have been permitted to join two of the London Pigeon Clubs. The diversity of the breeds is something astonishing.

Darwin attributed this wondrous variety to the nearly limitless power of selection: "Breeders habitually speak of an animal's organization as something plastic, which they can model almost as they please." He quotes one authority on the "great power of this principle of selection": "It is the magician's wand, by means of which he may summon into life whatever form and mold he pleases."

This optimistic notion—that diligence in selection can produce almost any desired trait by artificial selection of domesticated animals or cultivated plants—has inspired the customary extrapolation into nature's larger scales, and a conclusion that natural selection must work even more inexorably to hone wild creatures to a state of optimal design. As Darwin wrote:

> How fleeting are the wishes and efforts of man! how short his time! and consequently how poor will his products be compared with those accumulated by nature during whole geological periods. Can we wonder, then, that nature's productions . . . should be infinitely better adapted to the most complex conditions of life, and should plainly bear the stamp of far higher workmanship. It may be said that natural selection is daily and hourly scrutinizing, throughout the world, every variation, even the slightest; rejecting that which is bad, preserving and adding up all that is good; silently and insensibly working.

This common claim for organic optimality cannot be reconciled with a theme that I regard as the primary message of history—the lesson of the panda's thumb and the flamingo's smile: the quirky hold of history lies recorded in oddities and imperfections that reveal pathways of descent. The allure of perfection speaks more to our cultural habits and instructional needs than to nature's ways (good design inspires wonder and provides excellent fuel for boxed illustrations in textbooks). Optimality in complex structure would probably bring evolution to a grinding halt, as flexibility disappeared on the altar of intricate adaptation (how might we change a peacock for different environments of its unknown future).

In any case, leaving aside the abstractions of how nature ought to work, we have abundant empirical evidence that enormous effort in husbandry does not alwa bring its desired reward. Poultrymen ha never broken the egg-a-day barrier, a we are now trying to produce frost-resi tant plants by introducing foreign DN with techniques of genetic engineering b cause we have not been able to develo such traits by selection upon the natur variation of these plants. We do not kno whether such failures represent our ow stupidity or lack of sufficient diligence (time) or whether they record intrins structural and genetic limits upon th power of selection. In any case, selectio either natural or artificial, is not the pu veyor of organic optimality that our new papers and textbooks so often portra Limits are as powerful and interesting theme as is engineering triumph.

Indeed, Francis Galton himself, in th same book that promised so much for h man futures by controlled breeding, pr sented the most incisive metaphor I ha ever read to acknowledge the other side the coin—the limits to improvement in posed by inherited form and functio (Darwin was also intrigued by the subje of limits and devoted more attention this aspect of growth and developme than to natural selection itself—see h longest book, the two-volume *Plants a Animals Under Domestication,* 186 Following the optimistic concept of unr stricted molding, we might view an orga ism as a billiard ball lying on a smoo table. The pool cue of natural selecti pushes the ball wherever environment pressure or human intent dictates. Th speed and direction of motion (evolutio ary change) are controlled by the extern force of selection. The organism, in sho does not push back. Evolution is a one-wa street, outside upon inside.

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But suppose, Galton argues, organisms are not passive spheres but polyhedrons resting upon stable facets.

> The changes are not by insensible gradations; there are many, but not an infinite number of intermediate links . . . . The mechanical conception would be that of a rough stone, having, in consequence of its roughness, a vast number of natural facets, on any one of which it might rest in "stable" equilibrium . . . . If by a powerful effort the stone is compelled to overpass the limits of the facet on which it has hitherto found rest, it will tumble over into a new position of stability . . . . The stone . . . can only repose in certain widely separated positions.

Galton proposes no new force. The polyhedral stone will not move at all unless natural selection pushes hard. But the polyhedron's response to selection is restricted by its own internal structure; it can only move to a limited number of definite places. Thus, following the metaphor of Galton's polyhedron to its conclusion, the actual directions of evolutionary change are a dynamic interaction of external push and internal constraint. The constraints are not merely negative limits to Panglossian possibilities but active participants in the pathways of evolutionary change. St. George Mivart, whom Darwin acknowledged as his most worthy critic, adopted Galton's polyhedron as the basis of his argument and wrote (1871):

> The existence of internal conditions in animals corresponding with such facets is denied by pure Darwinians . . . . The internal tendency of an organism to certain considerable and definite changes would correspond to the facets on the surface of the spheroid.

If Galton's polyhedron ranks as more than mere verbiage, then we must be able to map the facets of genetic and developmental possibility. We must recast our picture of evolution as an interaction of outside (selection) and inside (constraint), not as an untrammeled trajectory toward greater adaptation. We can find no better subject for investigating facets than Darwin's own prototype for evolutionary arguments—changes induced in historical time through conscious selection by breeders upon domesticated animals. I can imagine no better object than our proverbial best friend—the dog—Galton's own choice for comparison with us in the very first sentence of his manifesto for human improvement.

We should begin by asking why dogs, cows, and pigs, rather than zebras, seals, and hippos are among our domesticated animals? Are all creatures moldable to o tastes and needs, and do our selectio therefore reflect the best possible beef a service? Or do some of the strongest a tastiest not enter our orbit because sele tion cannot overcome inherited features form or behavior that evolved in oth contexts and now resist any recruitment human purposes?

From the first—or at least since We ern traditions abandoned the idea th God had designed creatures explicitly f human use—biologists have recogniz that only certain forms of behavior pred pose animals to domestication, and th our successes represent a subset of ava able species, not by any means a chos few amidst unlimited potential. In pa ticular, we have recruited our domest animals from social species with hiera chies of rank and domination. In the bas "trick" of domestication—what we c "taming" in our vernacular—we learn t animal's own cues and signals, thus a suming the status of a dominant creatu within the animal's own species. We tam creatures by subverting their own natur behavior, not by altering it at will or to o will. If animals do not manifest a bas sociability and propensity to submit und proper cues, then we have not been able

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mesticate them, whatever their potential as food or beast of burden. As Charles ell wrote in 1832:

nless some animals had manifested in a ld state an aptitude to second the efforts man, their domestication would never ve been attempted . . . . It conforms itself the will of man, because it had a chief to nich in a wild state it would have yielded edience . . . it makes no sacrifice of its tural inclinations . . . . No solitary species . has yet afforded true domestic races. e merely develop to our own advantage opensities which propel the individuals of rtain species to draw near to their fellows.

The dog is our primary pet because its ncestor, the wolf *Canis lupus,* had volved behaviors that, by a fortunate accident of history, predisposed it for human mpanionship. Thus, our story begins ith a push onto a facet of Galton's polyedron. Domestication required a preisting structure of behavior.

We might readily admit this prerequisite, yet marvel at the stunning diversity domestic breeds and conclude that any ape or habit might be modeled from the asic wolf prototype. We would be wrong gain.

In science, we can usually formulate big" questions easily enough; the genius the enterprise lies in our ability to translate such ideas into palpable data that can elp us to decide one way or the other. We an readily state the issue of limits versus ptimality, but how shall we test it? In ost cases, we approach such generalities est by isolating a small corner that can be efined and assessed with precision. This ctic often disappoints nonscientists, for ey feel that we are being paltry or meanpirited in focusing so narrowly on one articular; yet I would rather tackle a ell-defined iota, so long as I might then dd further bits on the path to omega, an meet a great issue head-on in such illrmed complexity that I could only waf e or pontificate about the grand and inngible.

A standard strategy of this sort for the udy of limits lies in the field of *allomey,* or changes in shape associated with ariation in size. Two sequences of size ifferences might be important for studyng variation in form among breeds of omestic dogs: *ontogeny,* or changes in hape that occur during growth of individal dogs from fetus to adult; and *interspefic scaling,* or differences in shape mong adults of varying sizes within the amily Canidae, from small foxes to large olves. We might search for regularities n the relationship between size and shape these two sequences and then ask hether variation among dog breeds fol-

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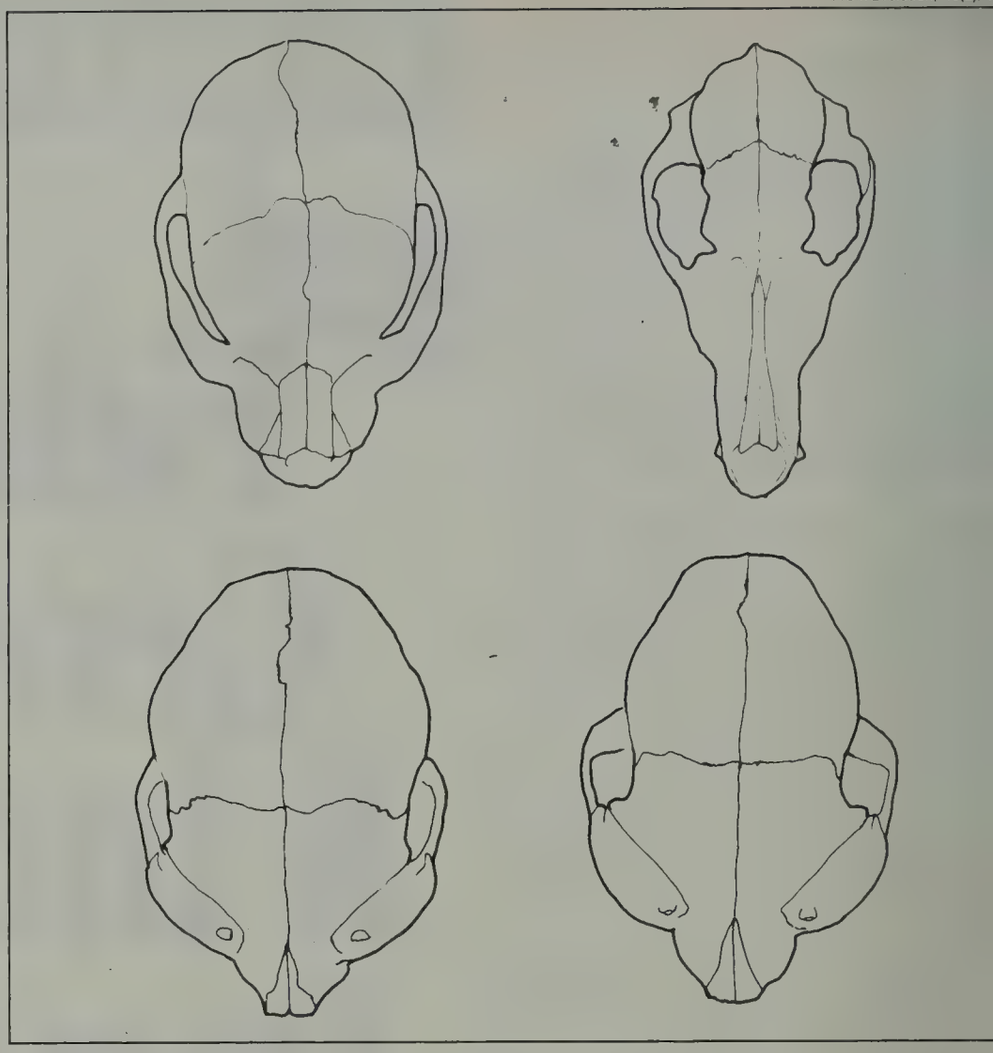
lows or transcends these patterns. If, for all their stunning diversity, dogs of different breeds develop the general shapes predicted for their size by the ontogenetic or interspecific series, then inherited patterns of growth and history constrain current selection along channels of preferred form. Growth and previous evolution will act as facets of Galton's polyhedron, favored positions imposed from within upon the efforts of breeders.

The biological literature includes a large but obscure series of articles (mostly *auf Deutsch*), dating to the early years of this century, on allometry in domestic breeds. These themes have been neglected by English and American evolutionists during the past thirty years, primarily because an overconfident, strict Darwinism had so strongly emphasized the theme of selection's power (and adaptation's extent) that the older subject of limits lost its appeal. But exciting progress in our understanding of genetic architecture and embryological development has begun to strike a proper balance between the external power of selection and the internal channels of inherited structure. I sense a welcome reappearance of Galton's polyhedron in the primary technical literature of evolutionary biology. As one example, the latest issue of *Evolution* (March 1986) contains an interesting study of ontogenetic and interspecific allometry in dogs by Robert K. Wayne.



Skulls of dogs (upper row) and cats (lower row) reveal the difference between neonates (left) and adult animals (right).

Wayne asks how inherited patterns of allometry might constrain the variety of domestic breeds. He finds, for example, that all measures of skull length (face, jaws, and cranium) vary little either in growth or among species in three senses: first, the ontogenetic and interspecific patterns are similar (baby dogs look like small foxes in the proportions of length elements); second, we note little change of shape as size increases (baby dogs are like old dogs, and small foxes are like large wolves); third, we find little variation among breeds or species at any common size (all young dogs of the same size have roughly equal length elements).

These three observations suggest that natural variation among canids offers little scope for fanciers to create breeds with exotic skull lengths. Wayne has confirmed this suspicion by noting that few adults of different breeds, from toy poodle to Great Dane, depart far from the tight relationship predicted by ontogeny or interspecies scaling: the length elements of a small breed may be predicted from the proportions of puppies in larger breeds or from small adult foxes.

Wayne points out that the criteria of artificial selection in domesticated races (the quirky human preferences imposed upon toy or fancy breeds, for example) must differ dramatically from the basis of natural selection in wild species—"the dog's ability to catch, dismember, or masticate live prey." If length elements are so constant in such radically different contexts, then their invariance probably reflects an intrinsic limit on variability rather than a fortuitous concurrence in different circumstances. Wayne concludes:

> Despite considerable variability in the time, place and conditions of origination of dog breeds, the scaling of skull-length measurement components is relatively invariant. All [small] dog breeds are exact allometric dwarfs with respect to measures of skull length. It is unlikely that such a specific morphological relationship has been the direct result of selection by breeders. Rather, a lack of developmental variation seems a better explanation.

When we turn to skull widths, however, we note variation where lengths showed constancy: puppies differ from adult foxes of the same size; puppies also turn into dogs of greatly altered shape, and small foxes are easily distinguished from large wolves by proportions of width elemen The material available to dog breede should be great.

Indeed, Wayne finds that dog bree vary greatly in width elements. (We mig be tempted to say, "so what; doesn't ever one know this from a lifetime of casu inspection?" Yet our intuitions are oft faulty. Wayne shows that small, snu nosed breeds have wide faces, not sho skulls or jaws. Readers might be chuc ling and saying, what's the difference doesn't overwide amount to the sar thing as undershort, as in the fat mar riposte that he is only too short for l weight. But the statements are not equiv lent, for we are comparing the lengths a widths with a common standard of bo size. Small breeds are the right length, b unusually wide, for their size.) The gre variation among dog breeds is not unifor among all parts, but concentrated in tho features that supply raw material growth and evolutionary history. D breeds form along the permitted paths available variation.

This study of internal potential helps to predict which features will form t basis for variety among breeds (not simp

hat the selector wishes, but what the electee can provide). But we can extend his insight much further to encompass he great differences in variety among domesticated species. If some parts of dogs iffer more among breeds because internal factors must supply the requisite variation, then perhaps, by extension, some entire species develop more diversity, not because human selectors have been more ssiduous or because human needs require uch variety, but because the internal facts of Galton's polyhedron are many, losely spaced, and varied.

Why do breeds of dogs differ so greatly, nd those of cats relatively little? (Cats ary widely in color and character of coat ut not much in shape. Nothing in the vorld of felines can approach the disparity n skull form between a stubby Pekingese nd an elongated borzoi.) Before we speculate about diminished human effort or lesire for Garfield versus Lassie, we hould consider the more fundamental act that available variation in the ontogny and interspecific scaling among cats ffers very little for breeders to select. Lions differ from tabbies far less than arge from small dogs while, more importantly, kittens grow to adult cats with only fraction of the change in shape that ccompanies the transformation of puppy o grown dog. Consider the figure (facing page) taken from Wayne's article and comparing, at the same size, neonates and adults of cats and dogs. Dogs have contributed to their own flexibility; cats, as ever, re recalcitrant.

Wayne makes a persuasive case that comparative diversity among domesticated species is more a function of available variation in the growth of wild ancestors than in the extent of human efforts. Horses change relatively little in shape during growth, and the heads of Shetland ponies do not differ much from those of he largest workhorses. Pigs, on the other hand, are second only to dogs in diversity of breeds. They are also unmatched among farm animals for marked change of shape during growth.

Amounts of intrinsic variation therefore set limits and supply possibilities to breeders. But even wild species with the most copious variation do not thereby become available for unlimited modification. Pigs and dogs vary in definite ways during their growth, and only certain shapes are available for selection at definite sizes. Wayne's most persuasive case for internal limits lies in his demonstration that sets of traits in a standard "ontogenetic trajectory" (a sequence of stages from puppy to adult) tend to hang together when they enter different breeds. Dog breeds are not

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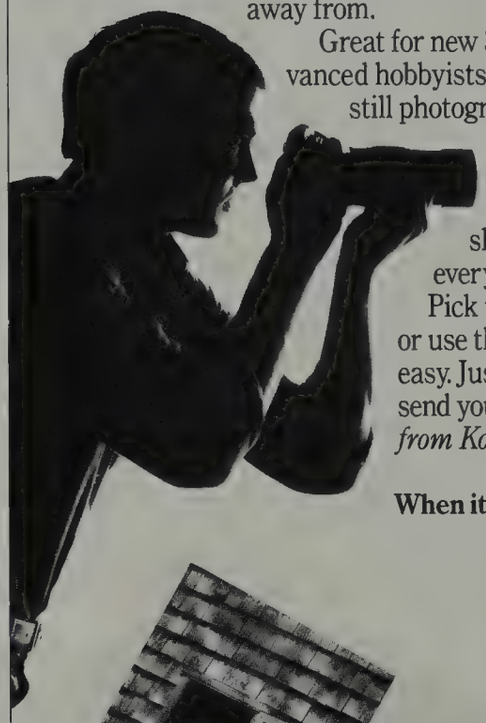

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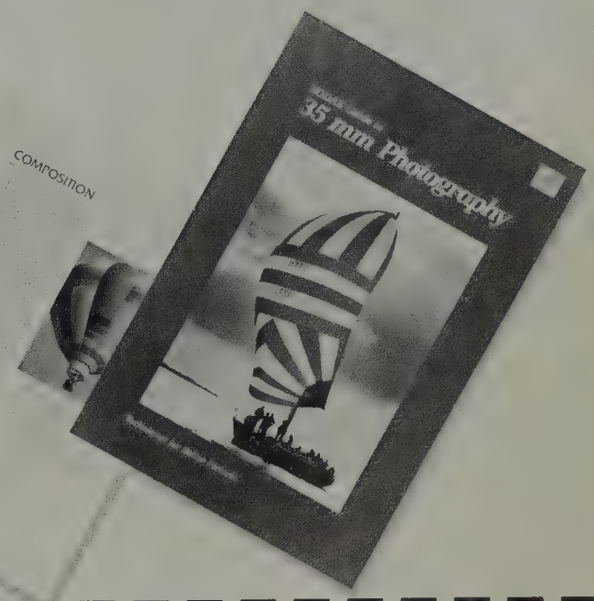

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a hodgepodge of isolated traits, each taken at will from any stage of ontogeny. Traits of juvenility remain associated, and many breeds, particularly among small dogs, continue to look like puppies when adult—an evolutionary process called *paedomorphosis* (child-shaped) or, if it happens by a general slowdown of change during growth, *neoteny* (literally, holding on to youth).

Wayne has shown that—without exception—adults of small breeds resemble the juvenile stages of large dogs more than the adults of other wild canid species (small foxes)—a convincing demonstration that inherited patterns of growth set possibilities of change. Dogs resolutely stick to their own trajectories of growth. "To some extent," Wayne concludes, "many dog breeds represent morphological snapshots between these developmental endpoints . . . . This suggests that small domestic dogs differ from foxes because puppies of small dogs cannot grow out of their distinctive neonate morphology."

We know, of course, that breeders can do many wonderful and particular things, from making a dachshund into a frankfurter to turning a chihuahua into a hairless rat or a sheepdog into a woolly mimic of its charges. But these peculiarities are imposed upon a basic and unaltered pattern set by constraints of inherited growth. The trajectory of ontogeny provides, as Raymond Coppinger states, a "rough first draft" for all breeds.

If ordinary variation in growth provides the main source for breeders, then a wild species' own juvenile stages are the primary storehouse of available change. Under this basic theme of limits, we may understand an old and otherwise puzzling observation about domesticated versus wild species. Over and over again, we note that domestic species maintain more juvenile proportions than their wild ancestors. We cannot explain this by smaller size (since domestic breeds are often larger than their ancestors) or by conscious selection on the old theme of planned optimality, for what possible common adaptive advantage could have inspired breeders to produce such a similar shortened face in Middle white pigs, the Niatu oxen of South America, and the Pekingese of the Chinese imperial court. The only sensible coordinating theme behind these similarities is retention by neoteny of juvenile traits common to most vertebrates.

If these shared neotenous traits of domesticated species are not products of direct selection by breeders, then what is the common basis of their origin? Most experts argue that these juvenile traits are spinoffs of the true object of selection—

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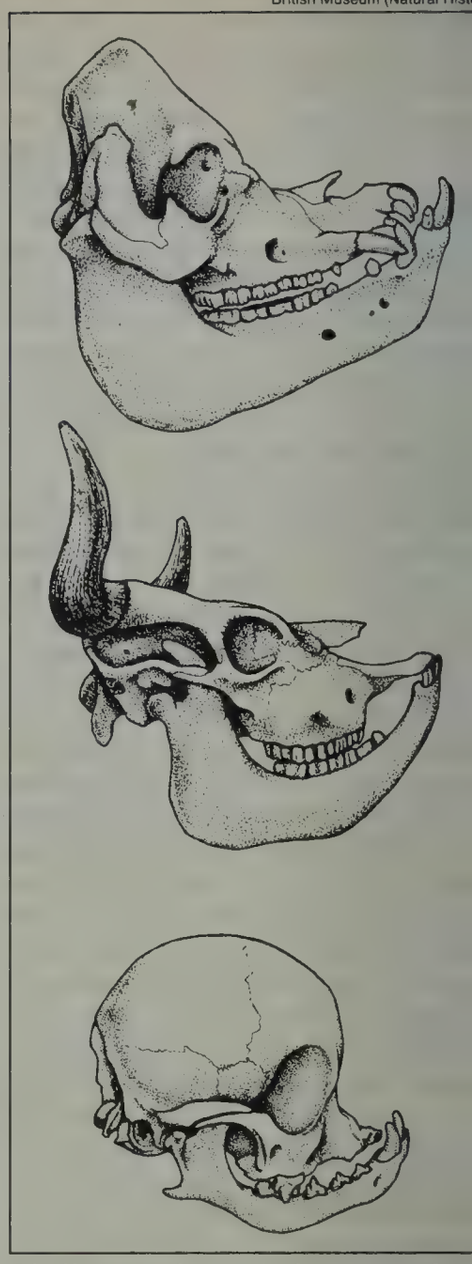
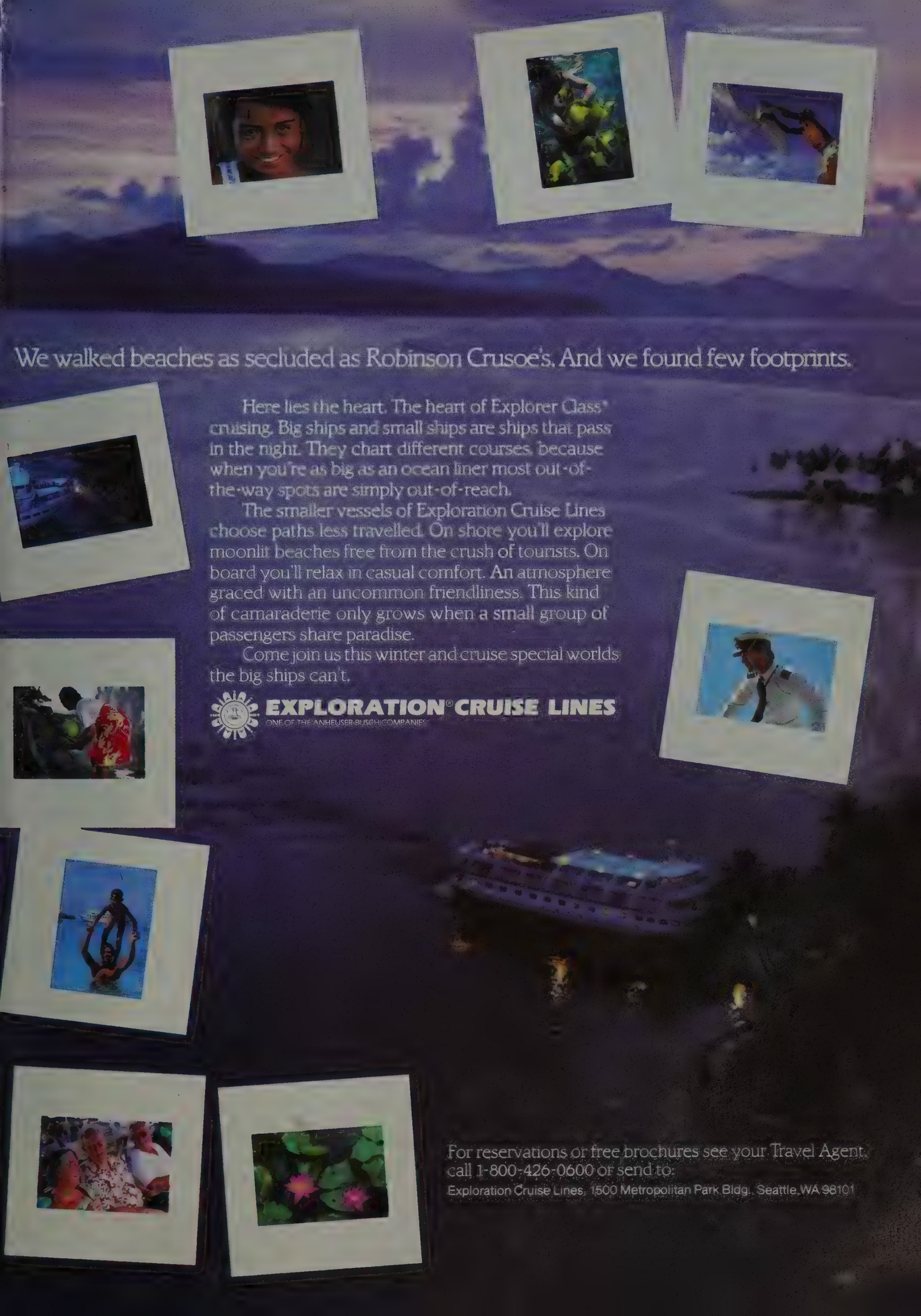


Skulls (top to bottom) of pig, ox, and Pekingese show these domesticated animals have shortened faces.

tame and playful behavior itself. Orga isms may vary as much in rates of develo ment as in form. By selecting for breedi only those animals that retain the favor juvenile traits of pliant and flexible beha ior past the point of sexual maturi humans hasten the process of domestic tion itself. Since traits are locked togeth in development, not infinitely dissociab as hopes for optimality require, selecti for desired juvenile behavior brings fe tures of juvenile morphology along for t ride. (We may, in some cases, also sele juvenile morphology for its aesthetic a peal—large eyes and rounded cranium for example—and obtain valuable spi offs in behavior). In short, these comm juvenile features are facets of Galto polyhedron—correlated consequences selection for something else—not the rect objects of human desire.

This theme of correlated consequenc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brings me to a final point. We have explored the role of developmental constraint in shaping many features of dogs—their difference in diversity from other domesticated species; the disparate contributions made by various parts of their bodies to the unparalleled variety among their breeds; the restricted sources of variation for construction of breeds, particularly the apparent limits imposed by tendencies for traits to "hang together" during growth.

We might view these themes in a pessimistic light—as a brake upon the power of selection to build with all the freedom of a human sculptor. But I suggest a more positive reading. Constraints of development embody the twin and not-so-contradictory themes of limits and opportunities. Constraints do preclude certain fancies, but they also record an enormous pool of available potential for future change. So what if the pool has borders; the water inside is deep and inviting. The pessimist might view correlated characters in growth as a sad foreclosure of certain combinations. But an optimist might emphasize the power for rapid change contained in the possibility of recruiting so many features at once. The great variation that dogs develop during their growth creates an enormous pool all by itself. A wide range of juvenile stages becomes available for recruitment by neoteny—a potential precluded if youngsters look and act like adults.

This great pool of potential has been used over and over again by breeders of domestic dogs. We should view it as the main source of their success, not the tragic limit to their hopes. My colleague Raymond Coppinger, of Hampshire College, has spent ten years promoting the use of guarding dogs (a great European tradition that never caught on in America) as an alternative to shooting, poisoning, and other mayhem in the protection of sheep from coyotes and other predators. He has placed more than five hundred dogs with farmers in thirty-five states. Coppinger notes the great, and usually unappreciated, difference between guarding and herding breeds. Herders control the movement of sheep by using predatory behaviors of adult dogs—stalking, chasing, biting, and barking—but inhibiting the final outcome. These breeds are as adult in their form as in their behavior; they display no neotenous features.

Guard dogs, on the other hand, simply move with and among the flock. They work alone and do not control the flock's motion. They afford protection primarily by their size, for few coyotes will attack a flock accompanied by a 100-pound dog. They behave toward sheep as puppies toward other dogs—licking the sheep face as a puppy might in asking for food, chasing and biting with the playfulness of young dogs, even mounting sheep as young dogs mount each other in sexual play and rehearsal. This neotenous behavior accompanies a persistently juvenile morphology, as these dogs maintain short faces, big eyes, and floppy ears.

Coppinger has raised guarding and herding dogs together from babyhood. They show little difference in behavior until puberty. Herders then develop the standard traits of adulthood—border collies begin to stalk, while retrievers and pointers live up to their names. But the guarders develop no new patterns and simply retain their youthful traits. Thus, a valuable set of features can be recruited together because they already exist as the normal form and behavior of juvenile dogs. Patterns of growth are rich reservoirs, not sterile strictures.

One tradition of argument identifies neoteny with all that is good and kind—"Except ye be converted, and become as little children, ye shall not enter into the kingdom of heaven." Yet I resist any facile transference between natural reality and human hopes if only because the dark side of social utility should teach us caution in invalid analogy.

Neoteny certainly has its dark side in social misuse. Konrad Lorenz, who, to put it as kindly as possible, made his life in Nazi Germany more comfortable by tailoring his views on animal behavior to the prevailing orthodoxy, often argued during the early 1940s that civilization is the analogue of domestication. Domestic animals are often neotenous; neotenous animals retain the flexibility of youth and do not develop the instinctive and healthy aversion that mature creatures feel toward deformed and unworthy members of the race. Since humans have therefore lost this instinctive power to reject the genetically harmful, Nazi racial and marriage laws are justified as a mirror of nature's mature ways.

Still, I cannot help noting, since dogs are descended from wolves, and humans really are neotenous in both form and behavior (without justifying Lorenz's fatuous and hateful reveries), that the neotenous of sheep-guarding dogs does fulfill, in a limited sense, one of the oldest and most beautiful of all prophecies: "The wolf also shall dwell with the lamb . . . and a little child shall lead them."

Stephen Jay Gould teaches biology, geology, and the history of science at Harvard University.

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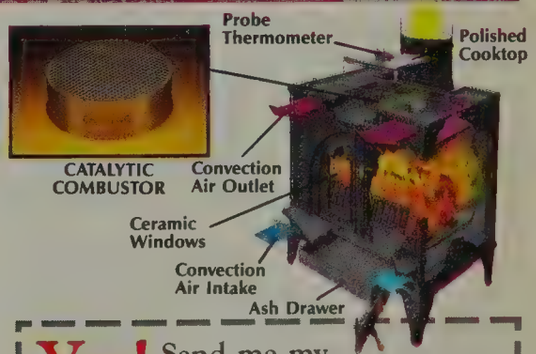

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We landed at the Havana airport on March 29, 1986, in a state of hopeful excitement because of the reported sightings of the ivory-billed woodpecker. This was confirmed immediately by our hosts for this year's expedition, Giraldo Alayón and Alberto Estrada of Cuba's Bureau for Protection of Flora and Fauna. They had glimpsed a female ivorybill two weeks earlier on March 16.

A year before, one of us (Short) had left Cuba with the faint hope that this majestic, but elusive, woodpecker was not, as many feared, extinct. For a week in late February and early March 1985, Short and a colleague, George Reynard, a bioacoustician associated with Cornell University's Laboratory of Ornithology, had searched for the ivorybill in remote eastern Cuba (see "Last Chance for the Ivorybill," *Natural History*, August 1985). They had found signs that an ivory-billed woodpecker had worked on some trees recently but had neither sighted nor heard one.

At Short's urging, Cuban colleagues, supported by their government, had agreed last year to search for the ivorybill in remote eastern areas with pockets of pine trees. They had mounted three expeditions to the region, and on the last one had sighted one female for a few moments at Ojito de Agua, about fifteen miles east of the spot where Short and Reynard had found signs of an ivorybill in 1985.

Now, eager to get into the field again, Short, Horne, and Reynard flew, along with Alayón and Estrada, to Holguín in eastern Cuba. After warm greetings from local government and museum officials, we packed our gear into a Soviet-made four-wheel-drive truck and drove for nine bone-jarring hours, the last twenty miles at night through mud and mire, to our quarters—a candle-lit temporary logging camp at Ojito de Agua.

On the day before our arrival, woodsmen had seen a woodpecker feeding in a valley east of the camp. In the morning, the woodsmen showed us various spots where the woodpecker had been seen feeding in trees. These signs of ivorybill activity surprised us because most of them were fresh diggings or holes carved in long-dead trees and stubs. Ivorybills mo typically scale bark off newly dead tre Recently excavated or scaled trees sh fresh reddish wood rather than the gray old deadwood. Most of the trees in t surrounding area were young, thin, s ond-growth pines among freshly c stumps. Scattered taller pines grew steep slopes and rocky places, and so dead tall pines rose above the cano Most of them were ill-formed, which h presumably spared them from cuttin Virtually all of these showed "working of the ivory-billed woodpecker.

AMNH

The ivory-billed woodpecker, as depicted by pioneer American ornithologist Alexander Wilson

On the morning of April 6, Eduar Solana of the Holguín Museum hea loud tapping near the Yarey River hea waters where the bird had been regula seen. Most of us waited at this site, b Horne moved to a slope a quarter m away. At 12:45 P.M., she observed a ma ivorybill at a recently debarked dead pi across the valley. Through her binocula she saw a black-and-white woodpeck with a red crest pecking at the lower ed of the debarked area. After twenty s onds or so, she ran up a path, waved to o of the guides on a nearby road to go for t others, and returned—only to find the iv rybill gone. This was our group's only su tained sighting. (Cuba has only one lar black-and-white woodpecker, the ivo bill. In the United States, we also have t common, large pileated woodpecker. black-and-white pattern is somewhat sim lar to the ivorybill's and can be confusi to observers, especially at a distance.)

On April 7, at 9:48 A.M., Estrada a two woodsmen, Emilio Perez and Arace Nuñez, spotted a male and a female ivo bill perched on separate tall pines ne

NE

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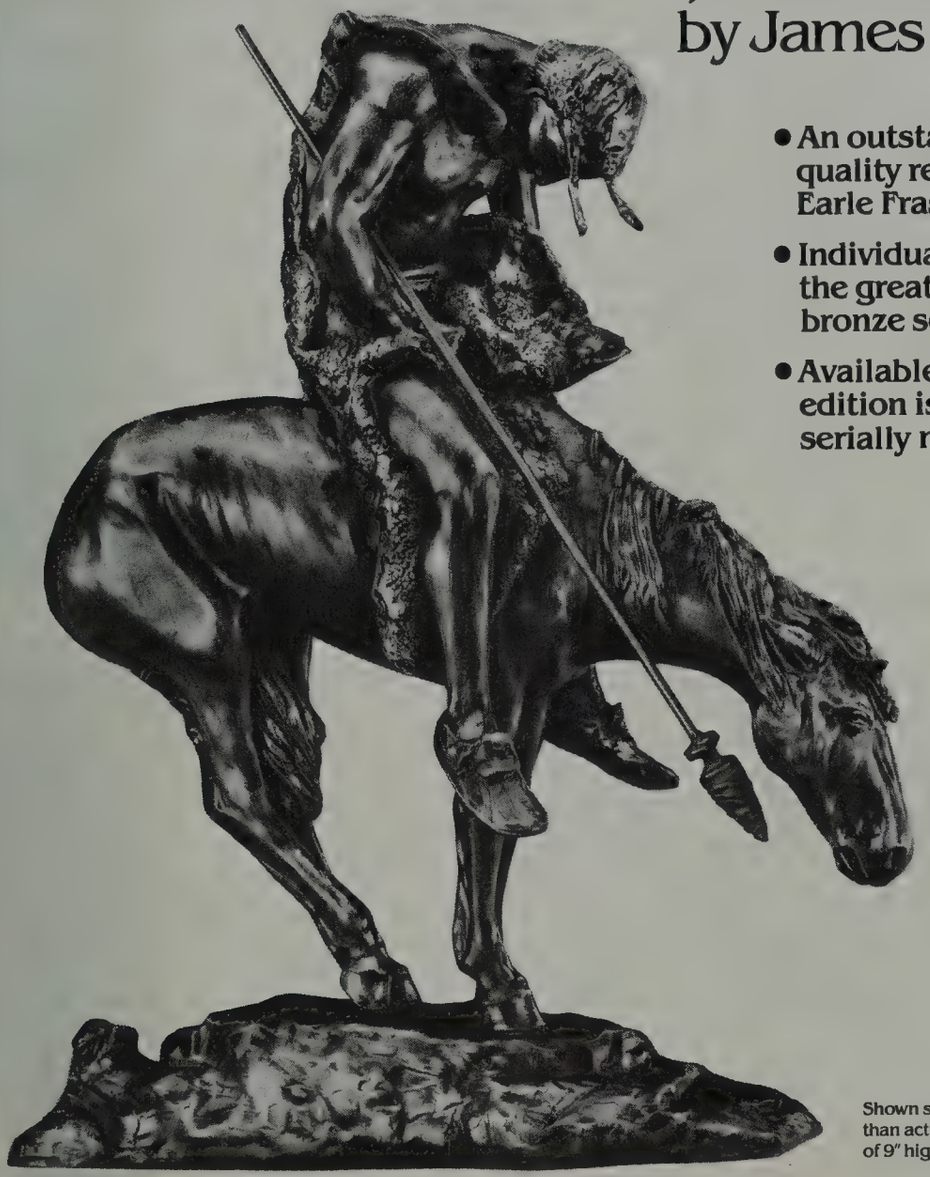

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where Solana had heard the loud tapping the day before. The two ivorybills flew off, dropping down into dense young pines on a rugged slope. These observations, from less than 200 yards, lasted for five seconds or so.

Despite large-scale searches from various points and at different times, no further observations occurred until April 10, at 7:00 A.M. Sitting alone on the site where Horne had seen the male, Reynard saw a large black-and-white woodpecker for a few seconds at about 100 yards. Flying low along a slope, it dropped down into the understory. He could not determine its sex, but most likely it was a female, since the red crest of a male would have been visible at that distance.

Taking the early stint across from the site where Horne and Reynard had observed the ivorybill, Short finally glimpsed a flying female ivorybill on April 12 at 7:20 A.M. The bird showed its white hindwing patches as it darted low, as if frightened, from the base of one slope, across the Yarey River to the other slope. Short saw it for about as long as it takes to raise binoculars to the eyes, and barely focused on the bird, seeing its crest, back, white-and-black wings, and long tail, before it disappeared low into the pines, about 200 yards away. After about thirty seconds, Short heard a single, emphatic "kyent" from the pines, then nothing more. After ten minutes, he played taped ivorybill calls and repeated them at ten to twenty minute intervals, with no response.

Later that day, atop the hill from which he had seen the ivorybill, Short paused while walking between sites and crouched to observe a different bird, a Cuban trogon. At 1:38 P.M., beyond the trogon, and low in a dead stub that had been pointed out by the woodsmen as a regular ivorybill feeding site, he spied a large black woodpecker's shape pressed against the trunk of the dead stub. Unfortunately, when he stood up to use his camera, both the trogon and the woodpecker flew away. The woodpecker, large, black, and with white flashing in the wings, dropped down the slope eastward, disappearing into the pines before Short could determine its sex. It was not seen again that day. On April 13, Alayón heard definite ivorybill calls from the slope south of our line of observation (we accept this report; undoubtedly some other reports of the guides and technicians may be invalid, but Alayón was well used to ivorybill calls from hearing our recordings, which are copies of those made in the 1930s by Peter Paul Kellogg and Arthur A. Allen near a nest in Louisiana).

On April 14, at 10:45 A.M., observing from the site where the first sighting occurred on the 6th, Reynard again saw a fast-flying, dropping black-and-white ivorybill, and again its crest color could not be seen.

The next day, three of us explored the pinewoods to the east, to Yarey Peak, and down into the Jaguaní River valley. The valley—open country with no human inhabitants—was full of birds in hardwoods. (It had been an area of mining, planting, and cutting a decade or more ago.) We saw some patches of tall pines on a few slopes of the otherwise cutover Sierra de Moa. The range, which might have provided a refuge for the ivorybill, was nearly fully cut over by foreign companies in the late 1950s, resulting in soil erosion and poor scrub growth.

On April 16, three of us, Short, Alayón, and Peña, planned to make a half mile sweep along the Yarey River, walking quietly in single-file through the trees on the slopes above the river. Observers were posted at the upper and lower ends of the area. Walking in line soon became impossible because the valley floor was covered with a bamboolike grass that crisscrossed in tangles between the trees. We quickly became separated. Short made his way slowly below the nest of a Cuban crow, was called at by the pair of crows, then crawled up the far slope and worked his way along the river. Spying several bark-worked trees on the other side, he recrossed the narrow river and saw undoubted ivorybill workings on large, live, but unhealthy pines (bases showing deadwood, little crown foliage). While Short was looking in the direction of the river, a male ivorybill crossed his field of view through patches of full sunlight and at a distance of about six yards. The bird was flying fast downstream, but seeing Short, it abruptly swung upslope and, flashing the shining white wing patches, bolted uphill and out of sight. At about 10:20 A.M., Short made his way downstream, where his companions on the "walk" had already arrived. They went on up the far slope, but could not find the male. Short walked back upstream to where Horne was observing. As he approached her excitedly to give her the news, he saw that she too was excited. At 10:20 A.M., Horne had seen two crows (probably the nesting pair) drop down and follow, low through trees and mostly out of her sight, a large black-and-white bird, an ivorybill. The crows made a swing at the woodpecker, which flew downstream, in the direction of Short's sighting at almost exactly that time. It probably was the same bird. We saw no further ivorybills on that day or on the 17th, our last full day in the field.

Thus, on the expedition, a male ivorybill and at least one female ivorybill w seen on seven occasions by six perso involving eight individual sightings. In dition, the birds were heard on two more occasions.

We recommended actions to save ivorybill to a Guantánamo provincial w life officer, who made a trip in to see and on Cuban television, when five ca eramen and reporters came up by mule the 13th and 14th of April. Our sugg tions included: cessation of all tree cutt within three and a half miles of the ivo bill site; no cutting in a belt, a little m than a mile wide, eastward to the Jagu Forest Reserve or in the Cupeyal For Reserve abutting the site area to the w monitoring of the ivorybills with a s cially appointed *guardacarpintero*; exc sion of all but scientists and wildlife m agement personnel from the area; limi girdling, by quiet means, to kill pi along the trails and thereby provide m feeding trees; and further searches to cate other possible ivorybills.

We returned to Holguín and more in views on April 18. The Holguín provin officials proved very supportive. On A 20, we flew across Cuba to Havana still more meetings. During a brief trip study other endemic Cuban woodpeck we got the news that the Ministry of A culture had officially closed the ivory area to logging activities. After a televi lecture at the Cuban Academy of S ences on April 25, we were assured various officials that every effort would made to save the ivorybill. The reaction the Cuban people to the publicity wholly sympathetic, and with Cuban entists supporting the moves, we exp that efforts to save the ivorybill will carried out effectively.

Whether or not these measures save the ivorybill will depend largely how many birds still exist, their gene ties, and their ability to endure in sub timal habitat until the pines reach mat height. April is a crucial breeding mo and the lack of drumming, which is tinctive and loud in the ivorybill, and sparse vocal activity hint that these birds are not breeding because of hun and other disturbances and the need move over large areas to find suffici food. The ivory-billed woodpecker n now have a chance, but we will be optim tic about the future of the species only more birds are found and protected.

Lester L. Short is chairman of the Am can Museum of Natural History's nithology Department; Jennifer F Horne is a research associate of the N tional Museums of Kenya.

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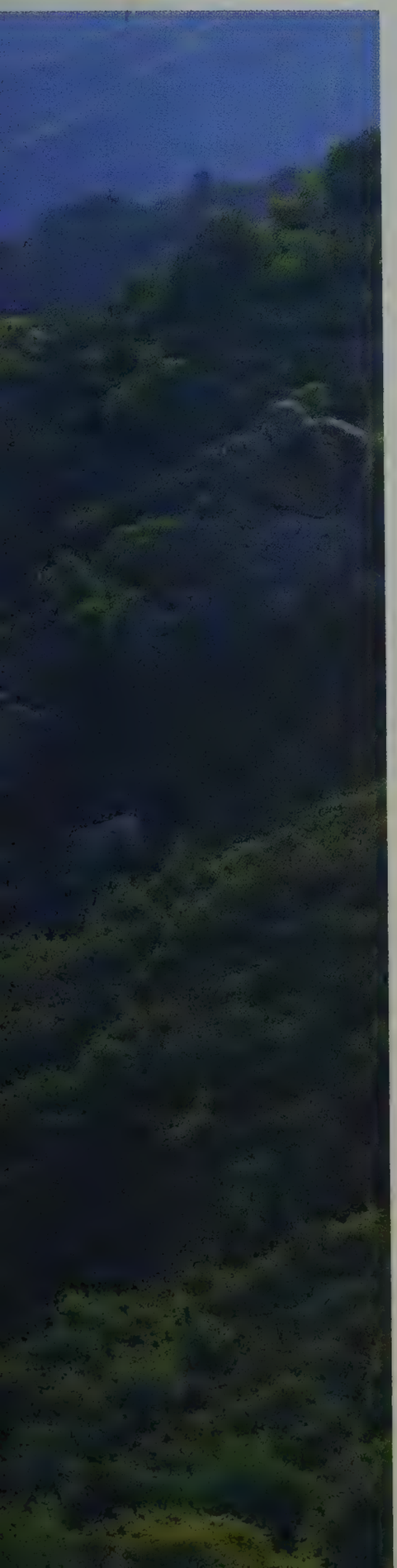
This Land

Jack W. Dykinga

Bradshaw Mountains, Arizona

by Robert H. Mohlenbrock



The rugged Bradshaw Mountains, in the southern reaches of Arizona's Prescott National Forest, were once prime gold country. The territory's principal back road follows the abandoned bed of an ore-hauling railroad, the Crown King branch of the Prescott and Eastern. Rocky and narrow, the road meanders from the near-ghost town of Cleator, in the eastern foothills, west to Crown King and then north to the city of Prescott.

Cleator (elevation nearly 4,000 feet) lies along the northern edge of the Sonoran Desert. The surrounding scrubland is dominated by the foothill paloverde, a small tree with spiny branches that belongs to the legume family, but saguaros occasionally stand as emblems of the desert, along with clumps of other cactuses—Fendler's hedgehog, Engelmann prickly pear, and teddy bear cholla. Other desert plants include the feather duster calliandra, ocotillo, and jojoba, all small trees with little leaves or with leaves modified into spines, adaptations that reduce water loss in the arid climate.

From Cleator the road begins a 2,000-foot climb to Crown King, leaving the saguaros and other desert-floor plants below. In their place appear round-topped woody plants that are about six to eight feet in height. Except for bare patches of rocky soil, the uniform vegetation gives the landscape a velvety appearance. This is chaparral, a plant community whose name is derived from the Spanish word *chaparro,* "dwarf evergreen oaks," referring to the shrub live oak, *Quercus turbinella,* which dominates the habitat.

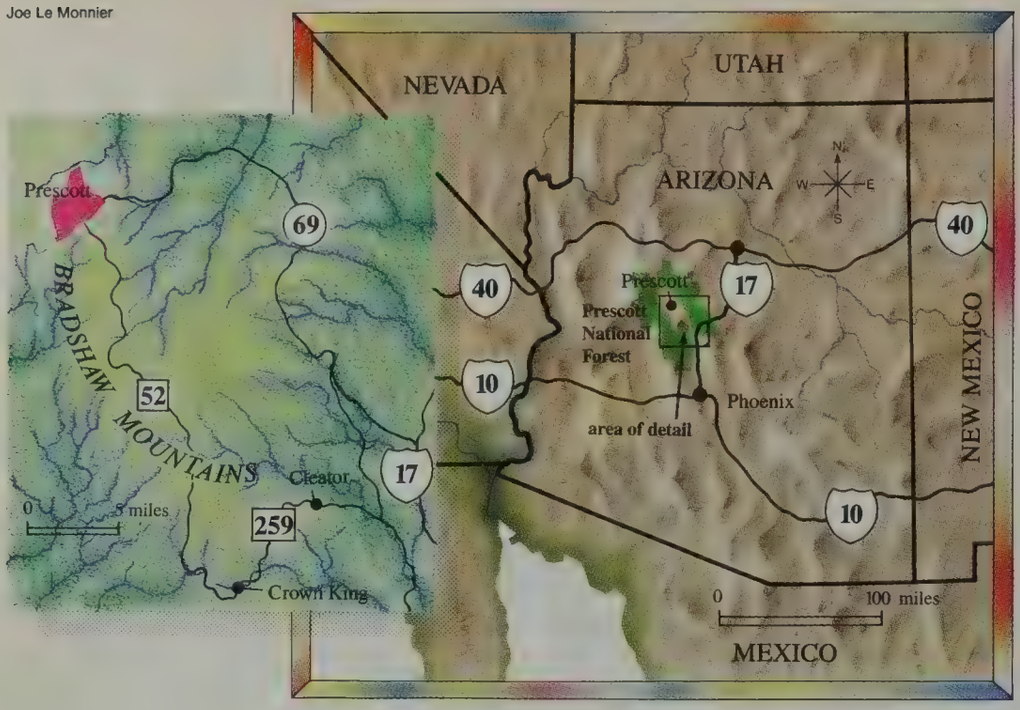
Although elevation is a factor in determining where chaparral occurs (most chaparral is found at elevations of from 3,000 to 5,800 feet), biologists attribute its presence to a Mediterranean-type climate characterized by cool, damp winters and hot summers. Similar brushy habitats, referred to as garigue, occur along the Mediterranean Sea; Corsica has a distinctive type, known as maquis.

In the United States, chaparral is found across central Arizona and again in southern California. Although these two habitats look similar, they differ in species composition and climate. In Arizona there

Tom Danielsen

A saguaro cactus, above, grows in the desert foothills of the Bradshaw Mountains. Brushy chaparral habitat, left, dominates at elevations of 4,000 to 6,000 feet.

Joe Le Monnier



Bradshaw Mountains

For visitor information contact:
Forest Supervisor
Prescott National Forest
344 S. Cortez
Prescott, Arizona 86301
(602) 635-2681

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are two major rainy periods—one from late November through December and one from July to September—and most chaparral growth takes place during the summer. In California, the rainfall is concentrated in the winter, and that is the growing season.

Daniel Axelrod, a botanist at the University of California at Davis, believes that the two chaparrals had a common origin but diverged more than two million years ago as a result of topographical changes. Newly formed mountain ranges in California confined summer precipitation to the coast, giving competitive advantages to those plants that were suited for long dry summers. In Arizona, the climate was less modified: the plant community continued to receive summer rain and remained similar to its original form.

The chief species in the Arizona chaparral are the shrub live oak, mountain mahogany, pointleaf manzanita, desert ceanothus, skunkbush sumac, and yellow silk-tassel. Most of these are evergreen shrubs with small, leathery leaves; dense, compact crowns; and deeply penetrating roots. Most rely on root sprouting as their major means of propagation. These modifications enable the species to survive the dryness of the chaparral habitat and the periodic fires that are fed by the tinder of fallen leaves.

In the chaparral, the rounded crowns of adjacent shrubs usually touch, forming a canopy that provides at least 60 percent cover. Lower branches often die for lack of sunlight, with the result that living branches enlarge and stems become gnarled and contorted. The canopy of many a shrub is supported by only a narrow strip of living tissue.

Root systems are extensive, penetrating quickly to great depths and spreading out laterally to capture all available surface moisture. One biologist measured a three-month-old desert ceanothus and found that its roots were three feet deep and two feet across.

Chaparral leaves are usually two or three times thicker than those of non-

Tom Danielsen

Shoots sprout after a fire

chaparral species and are covered with thick cuticle, or wax layer. In addition, th small openings in the leaves, called st mates, are confined to their lower surfac and are often embedded in deep crevice These characteristics inhibit water los The leaves of most chaparral shrubs ar also small, minimizing the danger of ove heating during the hot summer.

An important part of plant adaptatio in the chaparral is the ability to reproduc successfully despite the fires that ligh ning touches off once or twice each d cade, killing many plants and burning oth ers back. Those few species that depen on seeds for propagation produce seed that will not germinate until scarred b fire. The seeds may lie dormant in the so for many years before a fire activate them. The seedlings then start their live at the most opportune time, when cover reduced and the danger of further fire minimized.

Most chaparral species produce fe seeds, however, reproducing instead b root sprouting. A swollen root crown, c burl, develops at the base of the plan beginning in the seedling stage and enlarg ing each year until it is far thicker tha any of the main stems of the shrub. Th burl contains numerous buds that produc vigorous sprouts when activated by fire. chaparral shrub capable of sprouting fo lowing a fire has several advantages ove those that propagate through seeds, a pointed out by California botanist Te Hanes. One is that the plant retains it established place in the habitat; another i that nutrients and water in the root syster are immediately available, with the resu that the first year's growth is much mor rapid than that of seedlings.

Because of these adaptations, chaparra regains its normal appearance much mor quickly after a fire than other communit types. Characteristic shrub density in th chaparral returns within five years, an crown cover is established in seven years

In the Bradshaw Mountains, the chap arral is gradually replaced by a ponderos pine community at about 6,000 feet. Th increase in moisture and cooler climat are readily apparent on the road fron Cleator as it nears Crown King. At Crow King itself, a few weathered frame build ings nestle beneath the swaying pines They are all that remains of a minin community that had its heyday about th turn of the century.

"This Land" highlights the biologica phenomena of the 153 U.S. national for ests. Robert H. Mohlenbrock is distin guished professor of botany at Souther Illinois University at Carbondale.

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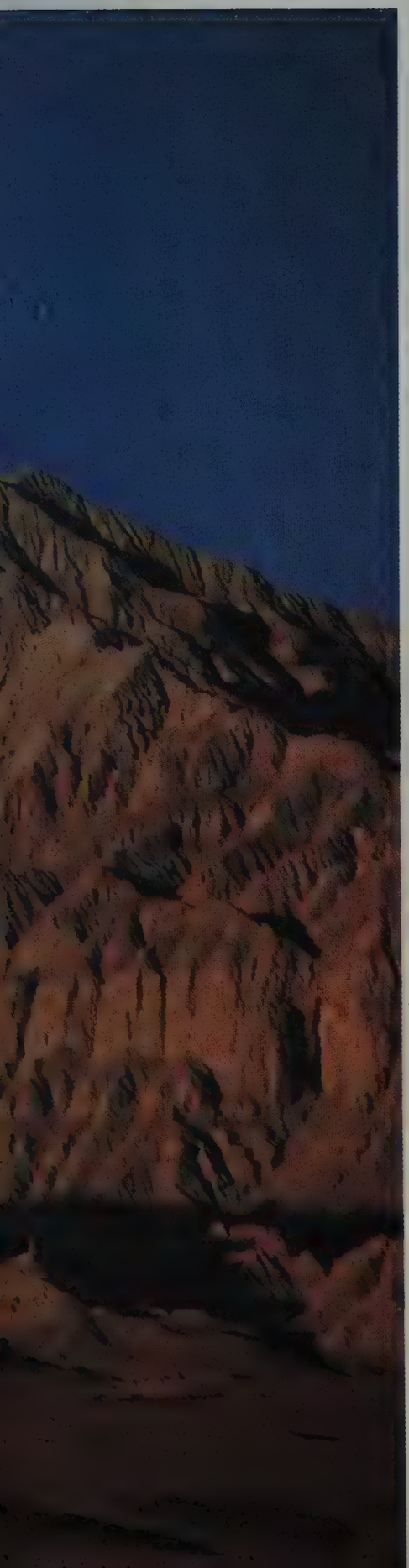
Below: Carved out of sandstone terraces on a plateau in the Trans-Himalayas, the citadel of Tsaparang was the capital of the medieval Tibetan kingdom of Gu-ge. Now abandoned, Tsaparang was a military fortress that housed a Buddhist monastery and Tantric temples. Opposite page: At the summit of the stone citadel is the Royal Chapel. Within, murals depicting Oriental deities have been preserved by the dry climate and protected by the isolation of this mountain outpost. The red structure on the left is known as the White Temple, where more medieval Tantric art survives.

In the Realm of the Buddha

An abandoned medieval citadel in the Tibetan Trans-Himalayas preserves treasures of Oriental art and reminders of ancient cults

Text by Frits Staal • Photographs by Adelaide de Menil

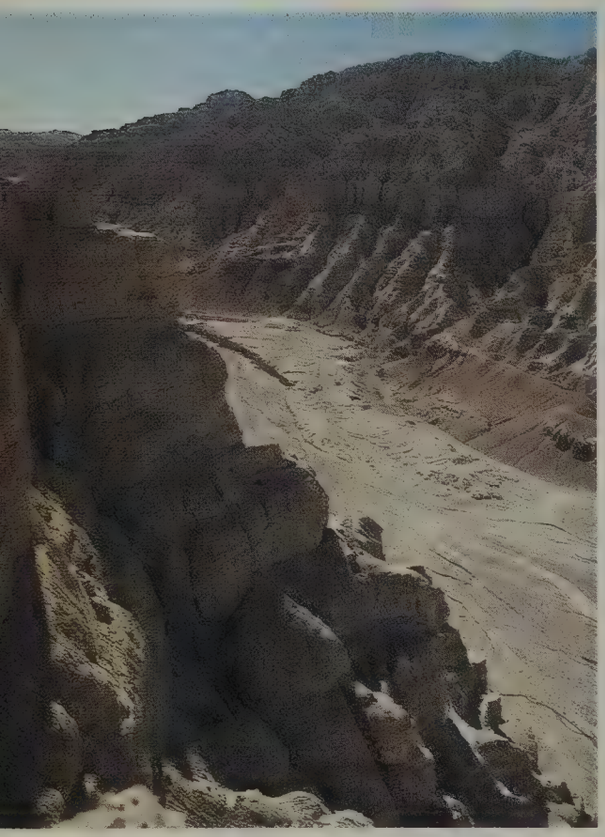


The watershed of the Himalayas does not lie along the line of its highest peaks, as in most mountain ranges, but about a hundred miles farther north. Many of the great rivers of India, therefore, have their source, not in the Himalayas, but in what Swedish geographer Sven Hedin called the Trans-Himalayas. The cause of this curious fact is that the rivers are older than the mountains they traverse. Before the Himalayas existed, the rivers flowed southward from present-day Central Asia and the Tibetan plateau into the Tethys Sea. During the Tertiary age, the chunk of land that was to become India drifted across the sea and collided with the Asian plateau, pushing up the Himalayas. The rivers had to go around the mountains or cut through them. At the same time, the upward surge of the Himalayas cut Central Asia off from the southern sea and its monsoonal climate. This separation, combined with the disappearance of the Ice Age glaciers, led to the increasingly dry climate and eventual desiccation of all Central Asia and Tibet.

The most important mountain of the Trans-Himalayas is Kailas (22,028 feet)—remote, mysterious, idealized in Indian myth, and a continuing challenge to explorers and adventurers. Immediately to its south lie two large lakes that have similarly exercised the imagination: Manasarowar and Rakshas Tal. A little farther south, but still north of the Himalayan range, stands another lonely giant: Gurla Mandhata (25,355 feet).

Four great rivers have their source in the Kailas region: the Indus, which takes its course around the western extremities of the Himalayas before flowing into the Arabian Sea; the Tsangpo/Brahmaputra, which flows to the east of the Himalayas before reaching the Bay of Bengal; and the Sutlej and the Karnali, which make their way directly through the mountains, cutting deep gorges that are a characteristic feature of the Himalayas. At the entrances to the gorges, the rivers have carved fantastic shapes in sandstone cliffs often more than a thousand feet high. While the Karnali has deposited its sediments near the northwestern border of Nepal, the Sutlej has created a monumental landscape at the foot of the northern slopes of the Kumaun Himalayas of India. Here peaks such as Kamet (25,447 feet) tower above a sandstone desert replete with natural spires, domes, and caves. At about 12,000 feet this plateau is sheltered, dry, mostly barren, and less cold than the vast wastelands of western Tibet that lie to its north. Visited in recent centuries by fewer outsiders than there are fingers on

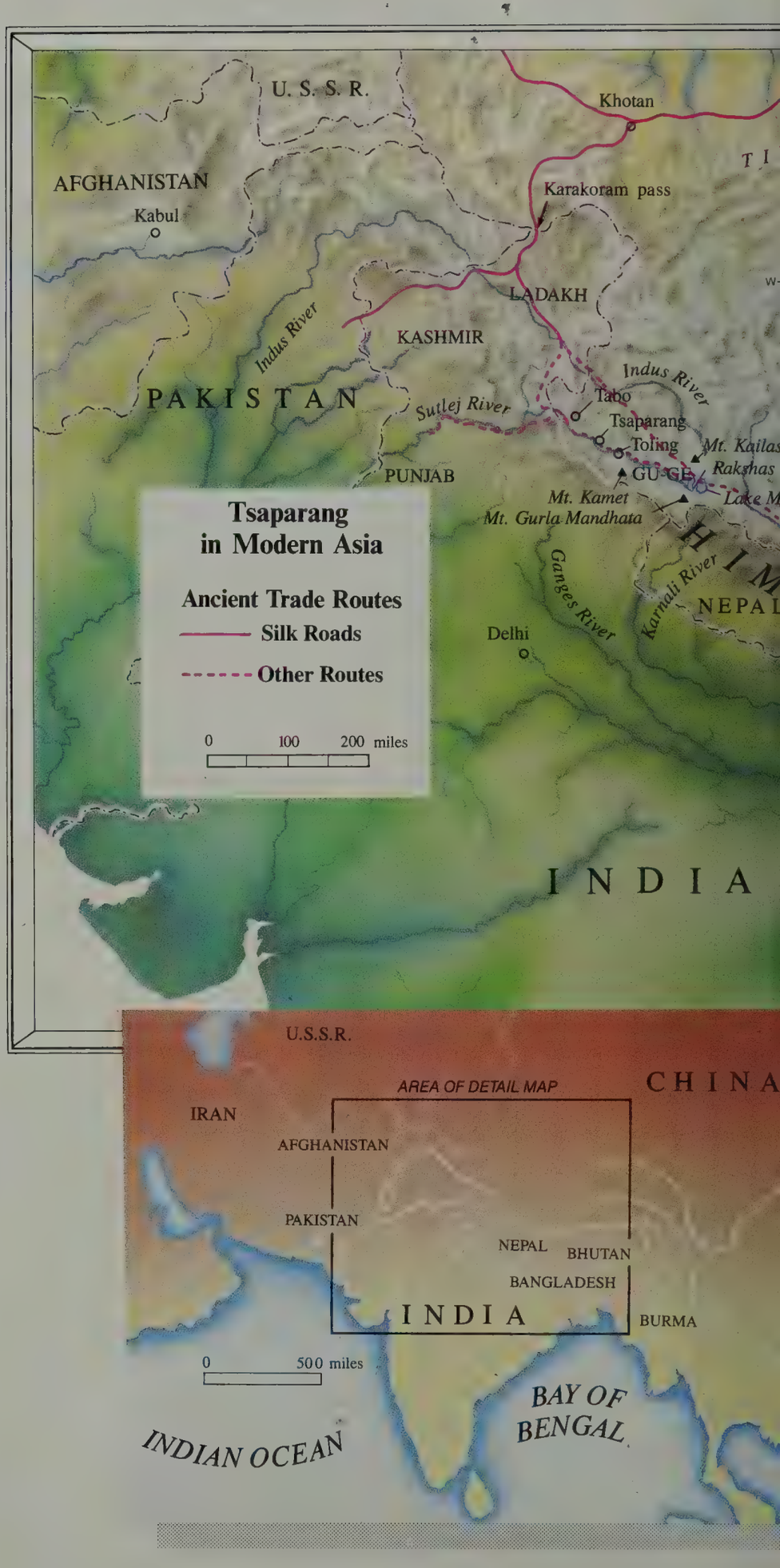
Looking down from the summit of Tsaparang, the man-made structures (upper left) are nearly indistinguishable from the natural sandstone formations of the Sutlej River valley.



one hand, this secluded land, once called Gu-ge (pronounced Goo-gay), has its own rugged charm. During the second half of the ninth century, a Tibetan king took refuge among the natural labyrinths of its rock terraces and founded his citadel, which came to be known by the name of Tsaparang.

South of the Himalayas, the Indus and the Sutlej are the largest rivers of the Punjab, the land of five (*panj*) streams (*ab*), which is as large as France and now occupies parts of India and Pakistan. Vedic nomads speaking an Indo-European language entered this fertile plain from the northwest before 1200 B.C. Moving east and south they crossed the Indus, the Sutlej, and finally the Ganges.

In the third century B.C., Alexander the Great crossed the Indus and the Sutlej. Greek geographers knew both rivers but were not familiar with their upper ranges on the other side of the Himalayas. During the first millennium A.D., Indians and Chinese referred to the Trans-Himalayan area of the upper Sutlej as Nation of Women because it was believed to be ruled by a line of queens. They also called



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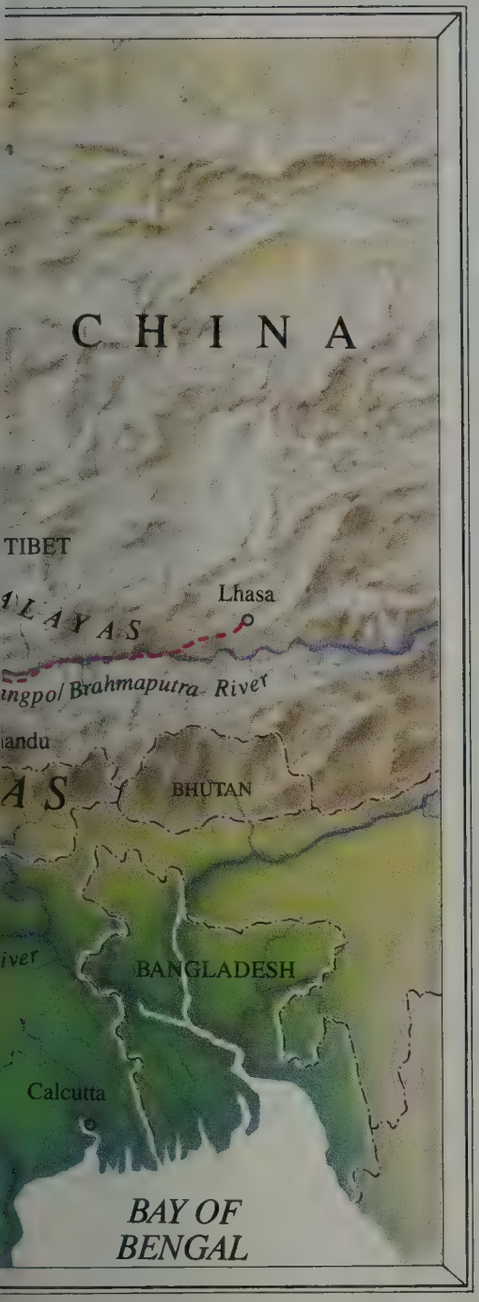

Tunnels inside Tsaparang are presumed to have been excavated to allow safe passage through the often-embattled citadel, as well as to gain access to water supplies from springs at the base of the plateau.

Golden Clan, and western Tibet has ver since been known for its gold. Prior to .D. 1000, an Indo-European language vas probably spoken here, as it was in ndia to the south and west, Kashmir to he northwest, and Sinkiang to the north.

Tibetan history started much later and ome 700 miles to the east. Like the his- ory of other early kingdoms, it was violent nd bloody. The first king of central Tibet, Nam-ri, was assassinated in A.D. 627. His on Song-tsen-gam-po succeeded his fa- her and established the Tibetan dynasty f Yarlung, which lasted two centuries nd engaged in frequent battles with 'ang China. The court of Lang-dar-ma, ast king of the Yarlung dynasty, was sub- ect to intrigues among rival nobles and ninisters. Lang-dar-ma was assassinated y a Buddhist monk in 842, and soon af- er, civil war broke out in central Tibet. In 866 some descendants of the royal family emigrated to the far west, where in due course three kingdoms were established: Maryul (modern Ladakh), Purang (the region south of the lakes of Rakshas Tal and Manasarowar), and the sandstone territory of Gu-ge on the upper Sutlej. The kingdom of Gu-ge became the most important principality, and Tsaparang, meaning "great residence," became its capital. An area the size of Taiwan, Gu-ge at the height of its glory counted many thousands of inhabitants. At present, if we exclude nomads and the Chinese population of Toling, a few hundred people live there. As for the citadel of Tsaparang, now called Tse-pu-lung, the Jesuit Nuno Coresma wrote in 1635: "It is impossible to count up more than 500 inhabitants, of whom a hundred are slaves of the rajah. . . ." In 1855, a visitor found fifteen or sixteen houses inhabited only in summer. Sixteen inhabitants were counted in 1908. When we visited Tsaparang last October, the first Westerners in almost forty years, there was only an old caretaker.

The earliest Tibetan kingdoms were not centers of civilization to compare with the Carolingian renaissance in contemporary France under Charlemagne or the high civilizations of classical Greece, Rome, India, or China. Buddhism, which may have acted as a civilizing influence by introducing Indian culture, reached Tibet relatively late. Founded in the sixth century B.C., on the southern slopes of the Himalayan foothills near the present frontier between India and Nepal, Buddhism spread throughout India and then to Ceylon (Sri Lanka) during the third century B.C. During the first century A.D. it crossed the western Himalayas to Central Asia and China. It reached Korea in the fourth century and Japan in the sixth.

According to Tibetan tradition, Buddhism was introduced into central Tibet in the mid-seventh century during the reign of King Song-tsen-gam-po, whose successors showed no great enthusiasm for it. In due course, central Tibetan Buddhism presented two different faces, reflecting antipodal origins. Indian Buddhism came to central Tibet from the south, while Chinese Buddhism, which also had its roots in India, came from the north, considerably Sinicized after five centuries.

Left: Hayagriva, the wrathful Hindu deity "Horse Neck," guards the entrance of the White Temple. The horse cult of Hayagriva was especially popular in Trans-Himalayan regions, where horses and horse breeding were more important than in India. The Buddhist monasteries of western Tibet are repositories of Indian art forms and cults that no longer exist in their land of origin. On the wall behind Hayagriva, and below, is Mahakala, another wrathful Indian deity, who is seen trampling corpses and drinking blood from a skull.

The difference between the two kinds of Buddhism could not fail to lead to a confrontation. Writings on the so-called Council of Lhasa tell of debates and discussions between Indian and Chinese Buddhists during the second half of the ninth century. While the underlying problems may have been political, the texts mention only doctrinal issues. The Indians defended the theory that nirvana can only be reached gradually, through lengthy, arduous, and sustained discipline and effort. The Chinese adhered to the hypothesis—originally Indian—that nirvana can be obtained suddenly and immediately, here and now. The Indian Buddhists are alleged to have won the debate, and so unity was temporarily restored. But the entire episode was a tempest in a teacup that was about to break, for Buddhism was under heavy attack from the outside. During the reign of Lang-dar-ma, Buddhists were persecuted and the Buddhist order finally suppressed. According to Tibetan tradition this led to the assassination of the king and the end of the Yarlung dynasty. It is more likely, however, that political upheavals forced the heirs to the dynasty to seek their fortunes elsewhere.

The prince who first undertook the long journey on horseback from central Tibet to the far west must have been an intrepid warrior—accompanied by loyal supporters, well provided with arms, and of sufficient wealth to acquire food and other needed supplies in an area where very little grows. He must have fought his way into that secluded territory against opponents whose identities we do not know. He or his immediate successors must have had sufficient ingenuity and technical expertise to construct a fortress: to carry stones, wood, building materials, water, food, and other supplies uphill and lay the foundations for the citadel of Tsaparang. Water is available on four sides of the plateau, but during much of the year it consists of trickles rather than streams. There are two springs beneath the citadel, and the first occupants constructed a stairway within a tunnel leading down to them. Another tunnel led to fortifications that overlooked the plateau. Enclosures inside were said to be stalls, although narrow passages to the summit would have been difficult for horses. The stonework has the look of a garrison. Fortifications there, and on the lower part of the hill, suggest that hostilities continued for a considerable period. This was confirmed by the Jesuit Father Antonio de Andrade who visited Tsaparang in August 1624—the first European to do so. He wrote that the king of Ladakh laid siege to Tsaparang, which was "an impregnable castle, well victualled, and there were 1,000 fire-arms with plenty of gun-powder and ball."

Buddhism probably played no role in the founding of Tsaparang, but in time, with survival assured, otherworldly concerns reappeared. Western Tibet may have originally been a stronghold of the Bon religion, which is held to have been the original religion of Tibet before Buddhism was introduced. The Bonpos themselves are unanimous in attributing their

Kathleen Borowik

origin to a country west of Tibet and Bon is, in fact, a remnant of an earlier phase of Buddhism probably introduced from Kashmir.

Some 300 miles to the northwest, on the other side of the Himalayas, the fertile valley of Kashmir was a center of Indian culture throughout the first millennium A.D. In its benign climate, Vedic traditions flourished, along with cults dedicated to Siva, Tantrism in Saivite and Buddhist forms, and all levels of Sanskrit learning. Kashmir was the home of some of India's great philosophers, grammarians, dramatists, poets, historians, ritualists, and authorities on medicine, aesthetics, and erotica. Not surprisingly, Kashmiri Tantrism was to become the predominant cultural influence in the kingdom of Gu-ge.

Tantrism, a development of the religions of India, is characterized by ritual ceremonies in which the ritualist identifies himself with a deity. Once he is a god, his ritual acts of yoga and meditation become divine acts of creation and procreation. Although Buddhist philosophy is atheistic and denies—at least in its later phases—an individual soul, the Buddha had from the beginning recognized a realm of deities, demons, and other supernatural beings. He did not prohibit their worship, propitiation, or ritual manipulation as long as it was recognized that these activities were inferior to joining his order and becoming a monk. Tantrism is therefore Buddhist, as well as Saivite or Hindu—although Hindu is merely a label attached by foreigners to all developments of Indian religion that are not explicitly assigned to another religious tradition. Tantric rites were practiced by wandering ascetics and yogis or institutionalized in Buddhist universities such as Nalanda. They developed in India between the third and twelfth centuries and were exported all over Asia, as far as Bali and Japan. The Buddhism that entered central Tibet from Nepal and India in the seventh century was already Tantric.

Tantric ceremonies begin with the creation of a mandala, a configuration of deities arranged around a central figure. The ritualist identifies himself through meditation with each of these, progressing clockwise from the outside until he reaches the center. Each deity has its characteristic iconography and is associated with a specific mantra. The mantras, meaningless syllables such as om, ham and hum, are recited aloud or silently. They are regarded as the bodies, or physical manifestations, of the deities. The ceremonies are conducted in cemeteries or in temples, by individuals or by teachers initiating pupils. Associates may participate or assist. There are female yogis who are beings of flesh and blood, and female demons, called *khan-dro-ma*, which means "she who goes in the sky."

The characteristic identifications of Tantric ritual are frequently described in terms of sexual union. Sexual activities were incorporated in the rituals, along with other acts of which earlier orthodoxy

Vairocana, meaning "radiant light," was a central figure of early Tantrism. Stucco images of the deity presided over Tsaparang's White Temple, where few images survived the ravages of China's Cultural Revolution of the 1960s. The best-preserved image is shown at left, while the empty seat of another Vairocana is shown below. The black-and-white reconstructions are based on 1948 photographs by Li Gotami.

Kathleen Borowik

had disapproved, such as eating meat and drinking alcoholic beverages. In Tibet, in the tenth and eleventh centuries, these tendencies grew malignant. Deities were propitiated with offerings of semen, blood, and excrement. Some ritualists not only indulged in indiscriminate sex, drugs, and drinking bouts but also kidnapped, killed, and ate men and women. The kings, as patrons of the official religion, were opposed to these practices and urged a return to orthodoxy.

In western Tibet, about the year 1000, King Khor-re went one step further: he abdicated in favor of his younger brother, entered the Buddhist order, and became a monk. Henceforward known by the name Ye-she-ö, or simply as a royal lama, he embarked upon an ambitious program of religious reforms. He sent young men to study in India so that they could return with the correct doctrine and practice. The most famous among these was Rin-chen s'ang-po (958–1055), a renaissance personality and one of the most important figures in the history of western Tibet.

Rin-chen s'ang-po instituted reforms on two different levels: with the help of a team of collaborators, he translated numerous texts from Sanskrit into Tibetan, and he founded or inspired the foundation of many monasteries, temples, and chapels, including those of Tabo, Toling, and Tsaparang. Henceforth, Tsaparang was not only a fortified capital but also housed a monastery, several temples, and chapels.

The Sanskrit texts that Rin-chen s'ang-po translated came mostly from northwest India, especially from Kashmir. With the help of his royal patron, he invited to Tsaparang Kashmiri ritualists and artists, including architects, sculptors, and painters. Unlike the art of central Tibet and all later Tibetan art, the early art of western Tibet had not been exposed to Chinese influence. The metal sculptures found there are indistinguishable from Kashmiri bronzes. A similar kinship may be presumed in the domain of painting, although no examples from Kashmir survive. Aside from the Tibetan murals, the only extant examples of the Kashmiri style of painting

Below: Inside the royal palace is a shrine dedicated to Samvara, interpreted as "perfect bliss." The murals within are preserved in almost pristine condition. Opposite the entrance, five Buddha figures, each with three faces and six arms, are distinguished from each other by pose and color. One mural, right, depicts Akshobhya, meaning "imperturbable." On the side walls of the chapel, ten wrathful deities, each with five heads and eight arms, face each other. One of these, bottom right, is Heruka, a fierce manifestation of Akshobhya.

are manuscript illustrations. One of these is a set of twelve illuminated folios from an eleventh-century metaphysical treatise found at Toling in 1933 and now preserved in the Los Angeles County Museum of Art.

The German sociologist Max Weber (1864–1920) argued that a close relationship exists between capitalism and Protestantism. His ideas were welcomed, especially in the United States, where they were interpreted as an endorsement of both. Capitalism and Buddhism are also closely linked. Monasteries established along the trade routes functioned not only as caravansaries but as markets and banks where merchants could trade or deposit their wealth and gain religious merit at the same time. The export of Buddhism cannot be separated from the export of other goods along these routes. Indian monks and merchants dreamed of China as a promising market for ideological and business interests, just as American missionaries, politicians, and businessmen were to do two thousand years later. What is remarkable about these exchanges across the formidable passes of the western Himalayas and Karakoram is that while material goods went in both directions, ideas came mainly from India. The Tibetan Buddhist writings include much of Indian literature, medicine, astronomy, logic, grammar, yoga, and Tantrism.

The monasteries, often built in strategic positions on the tops of hills, were defended by monks who were adepts in the martial arts. In later times, some of the great monasteries of central Tibet possessed a special category of fighting monks known as dap-dops. These were recruited from among novices who, although not academically gifted, were tough and preferably good-looking. The dap-dops wore distinctive hair styles and personal ornamentation and engaged in fights and various forms of sport, as well as homosexual activities. Since monks are not supposed to carry arms, they perfected a form of combat using large metal keys attached to leather thongs.

The combination of a military fortress with a Buddhist monastery and Tantric temples is not uncommon. The Buddha himself was the son of a king or chieftain and belonged to the second caste reserved for royalty and the military. He was trained in his youth to be a ruler, and so was taught riding, swordsmanship, archery, wrestling, and other martial arts. His first followers, and the majority of those who were later converted to Buddhism whether as monks or as laymen, were either members of the same military caste or merchants. Although the Buddhist ideal is nonviolence, the true doctrine must be defended against its enemies, and the history of Buddhism in Asia abounds in fighting monks, fortified monasteries, and rulers who adopt Buddhism because they believe they can put it to military advantage. In these respects the Tantric citadel of Tsaparang was no exception.

Mural, below, shows an archery contest, an event in which the young Prince Siddhartha excelled before he became a Buddha. The old man (left of the archers) was one of the four signs that opened the prince's eyes to the transitory nature of life. Right: A frieze above the entrance to the White Temple is done in an entirely different style and palette and may indicate influence from Iran or Central Asia.

Although Tsaparang is now situated in Tibet, and the few people who remain there speak Tibetan, its culture was predominantly Indian. Until the middle of the seventeenth century, Gu-ge was independent from Tibet and its capital, Lhasa. Then the whole of western Tibet came under the governance of the Dalai Lama and was exploited, as it is to this day, by officials from the capital.

The history of the kingdom of Gu-ge and of its capital, Tsaparang, is one of slow decline. The citadel gradually succumbed to a series of sieges, epidemics (for example, smallpox, mentioned by the Jesuit Francisco de Azevedo), and the continuing desiccation of the land. Located between Kashmir and central Tibet on a minor branch off the silk road, Tsaparang still attracted foreign visitors. There may have been Nestorian Christians and Manichaeans during the early periods, and there was a Christian community between 1626 and 1640, which in spite of its forlorn state was a source of valuable historical information. The few foreigners who visited the temples invariably complained of deterioration and neglect, which persist to the present day. Giuseppe Tucci, the first Tibetologist to visit Tsaparang, identified the sculptures and murals in an illustrated work that was published in Italian in 1936. In the same year, the Swiss geologist August Gansser visited the citadel, then so completely abandoned that he did not know its name, and described it briefly as the Dead City of the Rocks. Next came the German-Bolivian lama Anagarika Govinda. In 1948, he walked with his wife, Li Gotami, from the Indian side of the Kumaun Himalayas to Tsaparang. Some of her black-and-white photographs were finally published in 1979. In the meantime, the Chinese invasion and the Cultural Revolution, mostly executed by Tibetan youths at the prompting of Beijing, had taken their toll. The religious fervor of Lama Govinda and the political fervor of the Cultural Revolution have one thing in common: both focused their attention primarily on the stucco statues and neglected the murals that were partly hidden behind them.

What is left, as long as it lasts, is the exceptional contribution to the history of Tsaparang: exquisite Indian paintings nearly a thousand years old, the equal of the famous murals of Ajanta in India, Sigiriya in Sri Lanka, Dunhuang in China, or Horyuji in Japan. Their miraculous preservation is due to the dryness of the climate and their isolation in one of the remotest corners of Asia. □

Pussy Cat, Pussy Cat, Where Hav

Cats took various routes to get from the Old World to the New, and their coats tell the tale

by Andrew T. Lloyd

On the evening of August 27, 1981, I found myself surrounded by three police cruisers in West Haven, Connecticut. Residents of the quiet residential neighborhood had apparently become suspicious of the strange man poking around on their lawns and in their driveways. Some fast talking convinced the officers that I was just a population geneticist going about his business: cats. If they (and I) had been a little less busy, I could have told them in more detail how I came to be a minor disturbance in their town, but that would have required going back a bit.

Cats come in a multiplicity of colors, a fact that has delighted their admirers for thousands of years. This diversity is also appealing to geneticists, whose interest, however, is somewhat less aesthetic. Diversity is the stuff of genetics—Gregor Mendel would never have started his investigations if all peas were the same shape and color. Cats, like peas, prove to be a most amenable organism from which to obtain genetic information, for although they are extremely variable in color, all possible color variations are determined by fewer than a dozen genes. Simply by looking at a domestic cat, a geneticist can tell a great deal about its genetic makeup or, more precisely, about which alleles it carries. (An allele is a variant form of a gene. The human gene for eye color, for instance, has two common alleles: blue and brown.) And, as it turns out, these same alleles can often tell us something about where the cat's ancestors came from.

In contrast to most other domestic animals, the mating patterns of most cats are largely beyond the control or interest of humans. They are thus, in this respect, wild animals. In 1947, British geneticist A.G. Searle quantified the extent of variation among the cats of London, thereby putting into a scientific context the trivial observation that cats are variable and that the variations are heritable. In so doing, he started a new branch of biological science called cat population genetics, which exploits the variability of individual cats to investigate differences among cat populations.

Determining the genetic makeup of all

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Jeff Albertson; Stock Boston

Much about the genetic makeup of domestic cats—whether purebreds, as shown here, or free-ranging animals—can be told simply by looking at them. Below: This tabby clearly shows the presence of two alleles (variant forms of a gene): the one for orange and the one, known as blotched tabby, that turns stripes into whorls. Below bottom: All pure-white cats carry the dominant-white gene, which causes total depigmentation of the hair. Right top: Here three alleles interact: nonagouti, which produces a black coat; dilute, which turns black to gray; and piebald spotting, which results in a partly white coat. Right bottom: This calico cat also has a combination of three alleles: those for long hair, piebald spotting, and orange color.

Photographs these pages by Chanan

the cats in a population is obviously impossible, but obtaining a sample of a couple of hundred cats is sufficiently representative for most purposes. Sampling can be done by visiting SPCA shelters, by knocking on doors, or simply by walking systematically through the streets and alleys of an area, observing and recording cats in gardens and yards, under cars and on top of walls, grooming in the sun or running across the road. The cats are hardly disturbed, although as I have indicated, people occasionally are. In good light, trained observers can make a genetic diagnosis for ten genes in a running cat at fifty paces, a boast that could hardly be made for any other species.

In any discussion of genetic variability, the establishment of a wild type, or accepted norm for the species, is an enormous help. Each individual animal in the study can then be compared with the wild type. In the domestic cat, *Felis catus,* and its presumed ancestors, the wild cats *F. sylvestris* and *F. lybica,* the wild type is a mackerel tabby with alternating black-and-tan stripes. The black stripes consist of hairs that are fully pigmented along the entire hair shaft, while the tan stripes are composed of only partly pigmented hairs. Between the base and the tip of these hairs lies a band of depigmentation, which is what, at a short distance, makes them look buff or khaki. This partly depigmented hair is common in mammals (mice and rabbits, for example) and is called agouti after the South American rodent.

Many genes interact to determine features of the coat of the wild type domestic cat—its characteristic color, pattern, and length. Seven of these genes are known to occur as variant alleles, referred to as mutants, not because they are alien or particularly uncommon but only because they differ from the wild type (the Latin verb *mutare* means "to change"). Together with the wild type, these seven commonly occurring mutant alleles account for 99 percent of all types of cats observed in free-ranging populations. In the presence of the sex-linked orange mutant, for example, the black pigment is replaced, producing alternating stripes of orange and yellow instead of the wild

type's black and tan. Because this gene is carried on the X chromosome, females may carry both an orange and a wild type allele, a combination that gives rise to a tortoise-shell (black and orange) or calico (black, orange, and white) pattern. Males, having but one X chromosome, must be either orange or not. In this case, folk knowledge is true: calico cats are always female.

If a cat carries the nonagouti mutant, all the hairs are fully pigmented and the coat is a uniform black. Blotched tabby, a common mutant of the gene that affects the pattern of agouti and black hairs, turns stripes into blobs or whorls. The dilute mutant "washes out" colors, leaving gray for black and cream for orange. One gene determines hair length—long (the mutant) or short. The mutant allele known as piebald spotting causes a variable amount of the coat to be white. Dominant white, a mutant allele of another, unrelated gene, causes total depigmentation, the source of all-white cats. Individual cats usually carry more than one mutant allele; perhaps the most common cat on the streets of New York City, for instance, is black and white, which is both piebald and nonagouti.

Other mutant alleles tend to be rare or only locally common. One, the polydactyl mutant, leads to cats with extra toes, which are familiar to many residents of New England but extremely rare in most parts of the world. Similarly, the Siamese allele, which limits pigmentation to the extremities (ears, legs, and tail) and dilutes color on the rest of the body, is common enough in free-roaming cats of Southeast Asia and in pedigree cats elsewhere but rare in most other populations.

The first step in studying the genetics of any population of cats is to look at each cat in the sample and determine which genetic variants it carries. The next step is to tally up, for each gene, how many alleles are mutant and how many wild type. The mutant proportion is called the mutant allele frequency and is usually represented as a number between zero and one. Allele frequencies can be calculated for all the common mutants described above; the resultant numbers are referred to as

Early immigrants to New England and the Canadian Maritimes undoubtedly brought their cats with them. These founding cats left their mark on the New World. Up to this day, genetic similarities can be seen between various cat populations in the New World and those in the localities from which their ancestors came. For example, the cats of Amsterdam, Holland, still have a genetic profile close to that of New York City's cats. Similarly, definite traces of their British forebears can be seen in contemporary cats of Boston and other New England towns. (To date, less is known about the genetic connection between the cats of coastal France and Quebec.)

Eliot Bergman

the gene frequency profile of the population. Each population has its unique profile, and for the cat population geneticist, the interest lies in comparing the profiles of the populations studied and attempting to explain differences among them.

Since 1947, researchers have surveyed some 270 populations of cats from London to Brisbane and from New York to New Caledonia. One of the earliest discoveries was that the frequencies of mutant alleles varied markedly from population to population; as more information accumulated, it became clear that the variation among populations was not random but evinced a certain amount of pattern and order.

In 1979, I undertook a concentrated study of New England and the Canadian Maritime Provinces to document the variability in the cats of the area and try to determine its causes. My study built upon earlier work carried out in the region by Neil Todd, Ben Blumenberg, and their colleagues. In the end, my co-workers and I gathered data on 6,500 cats from thirty-five cities and towns between New York and Newfoundland. Such large sample sizes are possible thanks largely to sampling techniques that involve neither special expertise nor equipment beyond pencil, notebook, and perhaps a pair of binoculars. Normally, biologists studying the population genetics of free-ranging animals must settle for smaller sample sizes; at the least, their techniques commonly require catching the animals, often taking blood samples and spending a lot of time in the laboratory to generate comparable information. An added bonus of cat population genetics is that such research tends to fall at the low end of a scale of costs. Indeed, 95 percent of the funding for my study came from the pockets of the investigators themselves.

After two years of fieldwork, I was able to establish a gene frequency profile for each population and begin the analysis. First, I had to ask if the inevitable variation (the profiles were bound to vary to some extent) was worth explaining or if the whole area was essentially a single homogeneous regional population. Fortunately (I was working toward a doctorate at the time), the statistical tests revealed significant differences between populations for all eight of the genes considered.

Next, I wanted to determine if any obvious ecological variables—such as temperature, altitude, precipitation—were responsible for the differences. In some cases, the answer appeared to be yes. A correlation was found, for example, between the frequencies of the allele for long hair and temperature-related variables, such as latitude. This is the kind of readily explainable association that one would almost hesitate to predict. However, the same phenomenon has been documented in thirty-six populations in the British Isles and in sixteen populations from tropical Brazil. All other things being equal, hot places have far fewer long-haired cats than do cold places.

The frequency of the allele for all-white cats is similarly distributed in New England and the Maritimes. Although totally white cats are not common in any population, the proportion tends to rise as one travels north. Again, the same phenomenon occurs in British cat populations. Although the reason is less obvious than for long hair, it, too, may be related to the environment. Many arctic and subarctic mammals and birds are white or turn

One type of cat common in Boston and some other parts of New England is the extra-toed, or polydactyl, cat. Cats with extra toes also occur in Yarmouth, Nova Scotia, a seaport town founded by immigrants from coastal Massachusetts. A search in nearby Digby, however, failed to turn up a single cat with extra toes; significantly, Digby was settled at the end of the American Revolutionary War by Loyalists from New York City, a town with essentially no polydactyl cats. Halifax was founded largely by Scottish immigrants but, in its early years, bought most of its provisions from Boston traders. The cats of this city, then, are a mix of elements from both Boston and the Scottish islands.

Eliot Bergman

white in winter. In snow-covered environments, white coloration may provide camouflage. Or it may be thermodynamically advantageous. Animals in cold climates generally have heavy insulative coats or feathers. Paradoxically, overheating may sometimes be a problem in the far north, and white animals may be able to reflect a proportion of the intense solar radiation they receive.

None of the other alleles I studied were apparently affected by ecological factors, so I had to look elsewhere to explain variations in their frequencies. One mutant in particular—polydactyly—proved to have an intriguing history. History is the key word here because the more I investigated, the more I became convinced that the answers to my questions lay in the study of the interwoven history of cats and humans.

The first record of extra-toed cats in Boston is in a letter written home by an Irish immigrant in 1848. Her casual description of these cats suggests they were common and had probably been present for some time. Today about 15 percent of cats in Boston are polydactyl. These cats are conspicuously absent from British (and other European) populations, which was unexpected since cats first arrived in New England in the company of British colonists. In fact, no domestic cats existed in the New World until brought from Europe. The polydactyl mutant must have arisen in the New World, almost certainly in Boston. Most likely, it has been maintained there by chance and perhaps by human preference for the unusual. Cats with up to ten extra toes are found elsewhere in the Northeast, but generally, the farther one gets from Boston, the fewer the polydactyl cats encountered.

Cats seem to migrate in three main ways: under their own steam at extremely slow rates (moving less than one mile per generation, a gene present in one of the earliest Boston cats might now be approaching New York, having passed through two to three hundred generations on the way); in company with migrating people as part of the family; and as hitchhikers on commercial trading ships. The two places outside Boston with the highest frequency of polydactyl cats are Yarmouth and Halifax, Nova Scotia. The original inhabitants of Yarmouth, some 270 miles northeast of Boston, emigrated from coastal Massachusetts in the mid-eighteenth century, traveling on small ships or on their own fishing vessels, and presumably brought their cats along with them. For the purposes of this study, Yarmouth can be viewed as a suburb of Boston. Just as many of the people living in Yarmouth today are descended from Bostonians, so the town's polydactyl cats also have roots in that seaport city. Other mutant alleles show a similar pattern: the frequencies for the orange, nonagouti, blotched tabby, and dilute alleles are virtually identical in the two communities.

Interestingly, while Yarmouth has a high frequency of polydactyly, not a single cat with extra toes was observed in the nearby town of Digby. Digby's cats derive from two sources, neither of which has a polydactyl connection: the original French Acadians and Loyalist refugees from the American War of Independence. Some of the Loyalists came from New York City, the last British enclave held at the end of the Revolutionary War and a city with essentially no polydactyl cats. Numerous Loyalists and their families left for a new life in Canada or England. Other Loyalists moved to Digby via Saint John, the "Loyalist capital" of New Brunswick; again, a town with very few extra-toed cats.

Like Yarmouth, Halifax has a strong but quite different historical connection to Boston. This town, now the largest city in the Maritimes, was founded in 1749 as a British counterpoise to the French fortress of Louisbourg on Cape Breton Island. The presence of so many polydactyl cats in Halifax can be explained by the fact that for the first six years of its existence, the city was supported as a strategic forward base at British government expense. Most of Halifax's provisions were purchased in New England and transported in Boston ships. Indeed, even earlier, when the first ships carrying immigrants from Europe reached Halifax, a fleet of Boston traders was waiting offshore, ready to do business with the new arrivals. Some of the newcomers—many of whom came from Scotland—probably brought cats with them, and not surprisingly, the genetic profile of Halifax cats is a mixture of elements from

Steve Solum; Bruce Coleman, Inc.

The coat of a black-and-tan tabby, right, consists of fully pigmented hairs and partly depigmented, or agouti, hairs. When all the hairs are pigmented—which happens when a cat carries the nonagouti allele—the coat is uniformly black, below.

Francis Lépine; Valan Photos

New England and the British Isles. Orange, nonagouti, and blotched tabby cats, for example, are characteristic of both Halifax and the Scottish islands, whereas the frequencies for other alleles—such as dilute, piebald spotting, and of course, polydactyly—are high in both Halifax and Boston.

History, it turns out, can explain a great deal about the present-day distribution of cat genes. As the Halifax situation suggests, we can even trace some North American cats back to their European forebears. New England and the Canadian Maritimes were originally colonized by three main groups of people: broadly speaking, the French settled in the north, the British to the south, and the Dutch, albeit briefly, in the Hudson River valley. European cat populations are known to differ from each other, and much of the variation observed today in cats of the former colonies was undoubtedly translated more or less intact from Europe.

The cats of New York are a good example. Unlike its New England neighbors, but remarkably like Amsterdam, New York City has many cats with piebald spotting, a high proportion of short-haired cats, very few orange cats, and no polydactyl ones. New York was founded in 1626 as a Dutch colony and together with Fort Orange (now Albany) was called the New Netherlands. The human population of New Amsterdam on Manhattan Island was 300 in 1630, 450 in 1646, and 1,500 at the time of the English takeover in 1664. Up the Hudson River valley, the population at that time was much smaller, perhaps amounting to 200 souls. Compounding all the gene frequency differences between two populations into a single measure, we get what is called the genetic distance. Despite the geographical and temporal gulf separating them, the genetic distance between the cats of New York City and those of Amsterdam today is less than that between New York and all but three New England populations (New Haven, Boston, and Providence). By contrast, the cat population of Albany was not large enough to resist the effects of immigration overland from the Connecticut River valley, and today Albany has a typically New England profile.

My study left me confident that, with cats at any rate, the genetic makeup of a population's founders exercises a powerful and lasting effect on the subsequent genetic profile of that population. With humans, the situation is much less clear. A genetic survey of a sample of today's New Yorkers, for example, would reveal little similarity with the people of Holland; massive successive waves of immigration have swamped the initial effect. Historians should perhaps take note: where conventional historical documentation is scanty or absent, an analysis of the existing cat populations may provide valuable clues to the early history of an area.

I am currently beginning an analogous study of the feral pigeon (*Columba livia*). Like cats, these birds are visibly polymorphic, as a cursory look at any group of pigeons in the parks of our cities will demonstrate. I hope this work will ultimately produce complementary information to compare with the now substantial body of cat data. Such a transfer of similar techniques to study very different organisms is commonplace in science, but this must be the only one that can be said to put the cat among the pigeons. □

The "horns" of the European stag beetl
*(*Lucanus cervus*), left, are actuall*
powerful mandibles. Air pockets withi
the outsized jaws lighten the load. Th
*forked fungus beetle (*Bolitotheru
cornutus*), facing page, is foun*
throughout the eastern United State

Paintings reproduced from *Insects, Etc.: An Anthology of Arthropods Featuring a Bounty of Beetles* by permission of the publisher Hudson Hills Press. © 1980 Schirmer/Mosel Verlag GmbH und Bernard Durin.

On the Dilemma of Horns

If long horns give fungus beetles an edge in mating, why do so many males have short horns?

Text by Luther Brown and Larry L. Rockwood • Paintings by Bernard Durin

The two males squared off, each ready to rout the other from its turf. They clashed head-on, horns locking as they grappled. After a few minutes of twisting and shoving, one contestant gave a final thrust, flung its rival from the field, and stood alone on the smooth fungal shelf jutting from the bark of a dead oak. The vanquished beetle had plummeted to the forest floor. Might—the bigger beetle with longer horns—had again won out.

A diverse group of insects, horned beetles have on their heads or thoraxes projections resembling horns, antlers, or tusks. The horns of some of these beetles are of enormous size and elaborate shape, and the varied shapes, sizes, and textures have long attracted the attention not only of entomologists but also of curious children and amateur naturalists. The scarab, often associated with ancient Egypt, is horned, as are the aptly named stag and rhinoceros beetles. Male beetles of the South American species *Golofa porteri* have thoracic horns as long as their other sections—the abdomen and head—combined. Males of the African dung beetle *Onthophagus rangifer* flaunt branching horns that resemble the antlers of caribou. Some species bear unicornlike spears, while others are adorned with forked, scooplike, serrated, or hair-fringed appendages.

Horns are usually restricted to males, but unlike the horns of hoofed mammals, beetle horns do not grow with age nor are they shed. Big males, however, usually have disproportionately large horns. In many species, male horn size is highly variable, and in some cases the males can be separated into those with large bodies and big horns, known as the majors, and those with small bodies and small horns, called the minors.

Many explanations have been offered for the occurrence of beetle horns, but recent arguments maintain that horns increase the males' mating chances, either by attracting females with their size or by being used in stag fashion to vanquish rival males. Observations demonstrate that males do indeed fight with their horns. Although postulated by Darwin, female preference for males with particularly large horns is less well documented. The significance of the great range in horn sizes apparent within a single species also remains obscure.

Because many species of horned beetles are tropical, rare, nocturnal, and adapted to a life under bark or in plant stem tunnels, few quantitative studies have been undertaken. However, a temperate-zone beetle called the forked fungus beetle (*Bolitotherus cornutus*) is an ideal organism for study. Found throughout the deciduous forests of eastern North America, the forked fungus beetle spends its entire life on or near the shelves, or brackets, of fungi growing on tree bark. For the past five years, we have been examining a population of these three-quarter-inch beetles in a forested ravine atop Salt Pond Mountain in southwestern Virginia.

Unlike many insects, forked fungus beetles are long-lived. Overwinter survival of adults nears 50 percent in Virginia, and some individuals are known to have lived at least five years as adults. During the summer, females of the forked fungus beetle lay about twenty eggs, one at a time, on the surface of a shelf fungus. Hatched larvae burrow into the fungus and tunnel through it while completing their growth. They spend a year in the larval stage, then pupate in chambers in-

J. M. Rowland; Robert and Linda Mitchell, Natural History Photography

Alan C. Graham

After courtship and mating, above, a female fungus beetle lays eggs on a shelf fungus. A South American dung beetle (Phanaeus imperator)*, right, uses its armature to roll dung into a ball that becomes a haven for developing eggs and a food source for larvae.*

side the fungus. After about one month, the new adults chew their way to the surface, where they continue to feed on fungal tissues and spores. Three species of fungus are common hatching sites for forked fungus beetles in our study site. Artist's conk (*Ganoderma applanatum*) and tinder polypore (*Fomes fomentarius*) are common on oaks and maples throughout the United States and produce hard, woody, perennial brackets that may last as long as ten years. The hemlock varnish shelf (*Ganoderma tsugae*), a much rarer fungus, produces a soft, mushroomlike annual growth that decays within one year. Fungus beetles feed only on fungus and probably help disperse fungal spores.

Male forked fungus beetles have a pair of horns that arise from the thorax and project forward over the head. A much smaller horn juts from the head itself and is used in opposition to the thoracic horns to form pincers. Horns vary greatly in length: some males carry horns half as long as their abdomens; others almost completely lack them and can be distinguished from the hornless females only by the small tufts of sensory hairs located on the male's belly.

One of the goals of our study has been to determine the importance of males' horns and thus to understand the forces

that have led to their evolution. Horns ar
used during at least two types of aggre
sive encounters. In one, two males mee
ing on a fungus engage in a head-on pus
ing match that ends when one retreats or
dislodged from the fungus and falls to th
ground. In the other type, a single ma
attempts to disrupt a courting pair. Unlik
that of most beetles, this species' cour
ship is lengthy, at times lasting more tha
an hour. Courtship begins when the ma
climbs onto a female and positions himse
so that his abdomen is over her hea
Short bursts of violent twitches, separate
by several minutes of quiescence, en

hen the male turns around to copulate or smounts and abandons the female. A litary male encountering a couple may tempt to lift the male off the female's ack by grasping him with his horns and ying him loose. This display of aggres-on can lead to a Pyrrhic victory; if the terloper wins and tries to mate, he may nd that in the process of disrupting the air, he has driven off the female. In some orned animals such as deer, a prolonged out between two rival males may allow a ird male to quickly mate with the avail-ble female. But the sedate moves of fun-us beetles and length of time they need to mate—at least ten minutes—make such opportunistic couplings unlikely.

Our first series of experiments was designed to show the importance of horn size to male mating success. Although past studies had demonstrated that big beetles could vanquish little beetles, they did not distinguish the effects of body size from those of horn size. We chose forty pairs of males; each pair had the same body length but different horn length. We placed each pair with a female in a small terrarium containing a piece of fungus and recorded their activities for ten days. The pair were then separated, and each male was placed in a terrarium with a new female. Observations resumed for another ten days, after which we reunited the original male pair in a new terrarium with a new female. Each male was thus observed when a potential competitor was present, when he was alone with a female, and again when his competitor was in the same chamber. During the periods when males were paired, the larger-horned individual was observed courting or mating 60 to 75 percent of the time. When the pairs were separated, all males courted with equal frequency and vigor regardless of horn length. These results suggest that when

males are of equal body size, the male with the longer horns has greater access to potential mates. This finding is consistent with observations of beetles in the field. In our intensively studied wild beetle population on Salt Pond Mountain we have found a relationship between a male's horn length and the number of times he is seen courting or mating: the larger the horns, the more often that male mates.

Horn size is an important determinant of the outcome of male combat. The several dozen fights we have observed in the field have always been won by larger-horned males. In our laboratory studies, however, fighting was rarely observed, so we were unable to distinguish between female preference for long-horned males and male aggression toward rivals. To resolve this problem, we modified our experiments. Once again we chose males of equal body size but unequal horn size. This time we tethered each male with a length of thread. Males were able to walk around freely in their terrariums but could not touch one another because their tethers were too short. Single females were introduced into each terrarium, and their choice of partner was recorded when they began to court. Surprisingly, equal numbers of the smaller-horned and larger-horned males were observed courting and mating. Although some subtle form of choice not based on horn size may be operating, we concluded that females do not evaluate males by horn size when mating and that female choice was probably unimportant in this mating system.

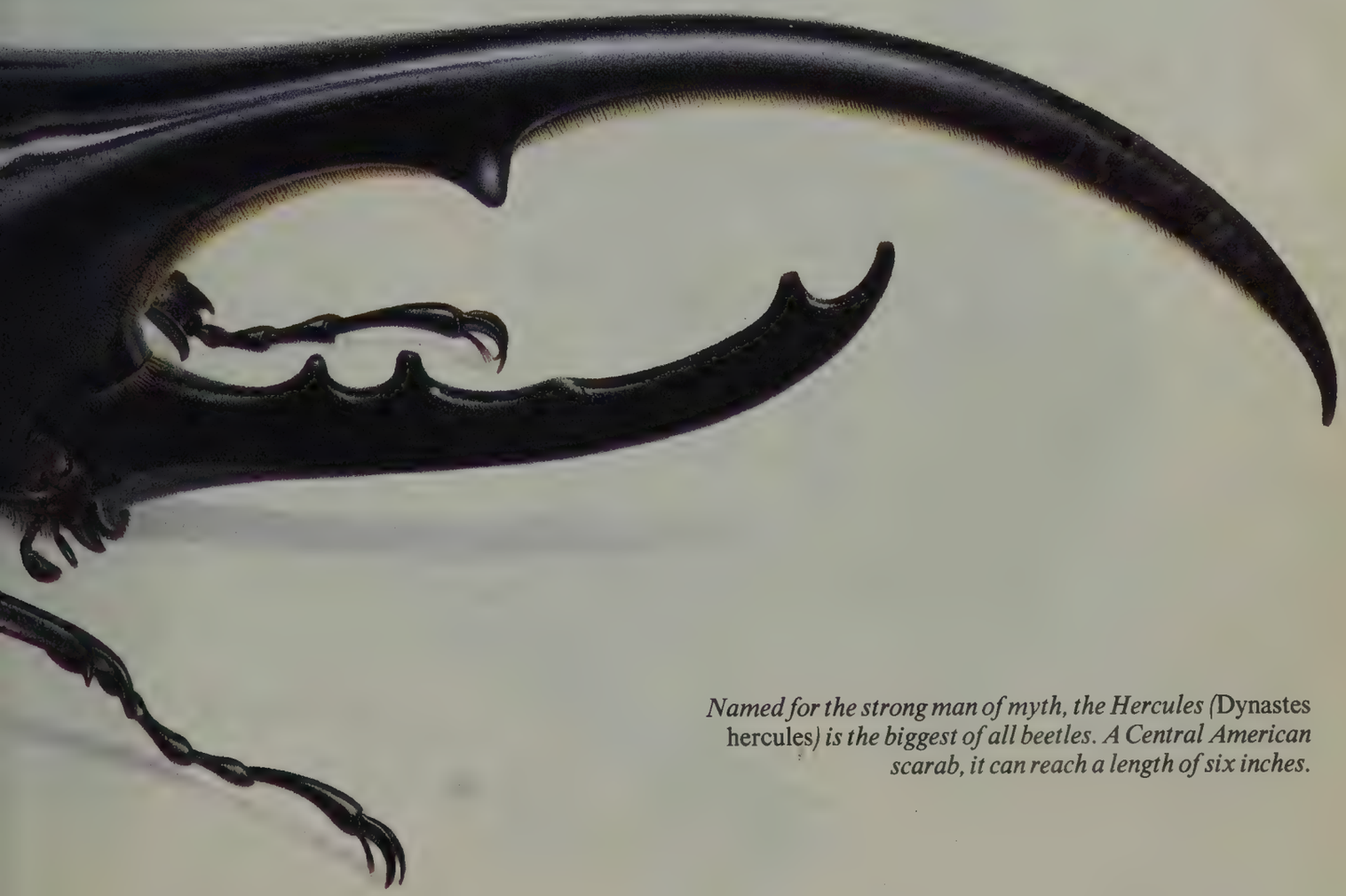
The laboratory experiments and field observations confirmed that horn length does determine male mating success, bu the primary vehicle is male aggression, nc female choice. In evolutionary terms, thi should mean that larger-horned male mate more often, sire more offspring, an so pass on more of their genes than d smaller-horned males. Why then are ther so many small-horned males in the wil population? The answer depends upo whether the trait is genetically dete mined, in which case small-horned male may father offspring by behaving diffe ently from larger-horned males or by be ing favored by females under special ci cumstances.

The genetics of horn size can be invest gated by mating virgin females to males c known horn size and raising the larva under controlled conditions and on th same diet. (Virgin females, also the proc

ɛt of larvae raised in isolation, are used ɛcause unmonitored adult females may ɛ storing sperm from previous matings.) ɔmparison of the sons' horns with their thers' should reveal the pattern of inher- ance. When we conducted this experi- ent, an analysis of more than 150 n–father comparisons showed that the ɔrn length of the father did not deter- ine that of the son's. This suggests that ariability in horn length is attributable to vironmental factors and is not geneti- lly determined. This nongenetic basis r horn length is also consistent with the ɔsence of female preference for long- ɔrned mates.

All three species of fungus—artist's ɔnk, tinder polypore, and hemlock var- sh shelf—used by horned beetles in our udy area pass through the same basic developmental sequence; each begins as a small nob of milky white tissue and grows rapidly into the commonly recognized shelf, which produces the spores that disperse the fungus. Eventually, the bracket is invaded by insects, worms, and other fungivores. Finally the bracket dies and is decomposed by molds and mildews. Forked fungus beetle eggs and larvae can be found within each of the three species of fungus. We supposed that each stage and species might represent a different food quality for the larvae. To investigate this possibility, we divided fungus development into early and late stages: early being an actively growing bracket; late being one that had stopped producing spores and was invaded by insects and worms. In another lab experiment, we cultured forty beetle eggs on each stage of each fungus species and raised the larvae under an approximation of natural conditions, controlling both temperature and periods of light and darkness.

The results were striking. Larval food source strongly affected both male and female growth and survival to adulthood. While almost 80 percent of larvae grown on artist's conk and varnish shelf survived, less than 10 percent grown on tinder polypore reached the adult stage. In addition, larvae cultured on early fungus stages always survived better than those on later stages. Similar patterns emerged when we evaluated adult body size, age at adulthood, and horn size. Larvae grown on artist's conk and varnish shelf emerged earlier, were larger, and had bigger horns as adults than did those feeding on tinder polypore. Larvae eating early stages of



*Named for the strong man of myth, the Hercules (*Dynastes hercules*) is the biggest of all beetles. A Central American scarab, it can reach a length of six inches.*

*The rhinoceros beetle (*Oryctes nasicornis*) is a nocturnal species found throughout Europe. Its affinity for rotting matter often leads it to deposit eggs in compost heaps, where the decay generates warmth.*

any fungus grew faster and were larg
than those eating fungus in later stages

The results of these experiments su
gest that female beetles are able to infl
ence the survival, body size, and ho
lengths of their sons by choosing the be
oviposition, or egg-laying, sites availabl
Indeed, females even act as if this is th
case. When presented with a choice b
tween the three species of fungus, femal
overwhelmingly prefer the two *Gan*

erma species—conk and varnish shelf—s oviposition sites, while rejecting tinder olypore. When presented with a choice etween different developmental stages ithin a fungus species, females select arly stages and reject later stages. This reference is particularly dramatic in the ase of the polypore, a species in which all ut the very earliest stages are shunned. As might be expected, females also show a trong preference for large fungi as oviposition sites, regardless of species or development, for the larger fungus will insure an ample supply of food for their larvae.

The evidence indicates that females can make adaptive choices that may ultimately affect their sons' horn length and their daughters' vigor and thus their reproductive success. Adaptive choices, however, are only as good as the options available. The distribution of fungus species and their developmental stages limit the choices a female can make. To examine the choices available to a wild beetle, we surveyed our study ravine and noted the species and developmental stage of all fungi. Almost 85 percent of the two hundred bracketed dead trees in our site supported only one species of fungus. Of the thirty trees supporting more than one species, twenty-nine had artist's conk and tinder polypore; none had all three fungus species. Similarly, almost 60 percent of the trees had only early or only late stages, and less than 1 percent offered the females a choice of both early and late stages of two fungus species. Furthermore, hemlock varnish shelf produces brackets irregularly, precluding the permanent occupation of the hemlock tree by a beetle population. A female looking for a place to lay her eggs has very restricted options. She can either continually search among the widely scattered fungus-bearing trees or settle for what is locally available and make the best of it. Most females appear to choose the latter route. The abundance of small-horned males may reflect the relatively few high-quality food resources in which larvae can grow into large-horned males. While females can potentially influence their sons' horn sizes, and thus the number of descendants they leave, they may not often have the opportunity to do so.

The activities of insects and other organisms are commonly constrained by the environment in which they live: animals may not always be able to find the most nourishing food item when they forage; females may not always come upon the most desirable male when choosing a mate; immigrants may not always locate the best habitats to colonize.

The perceptual abilities, mobility, and memory of an organism all interact with the environment to determine the limits of animal choice. Fungus beetles are quite sedentary and seldom move more than a few yards between fungi. Suitable feeding and oviposition sites are often rare and widely scattered, limiting a beetle's options. Thus the reproductive success of a female and her offspring ultimately depends on her ability to make the best choice in a less than perfect world. □

The Acid Rain Whodunit

Clues to the culprits lead in several directions, depending on the weather

by Kenneth A. Rahn and Douglas H. Lowenthal

For several years our research group has been interested in determining the sources of the haze, or smog, that can often be seen over New England. Our interest comes from the knowledge that one of the most plentiful constituents of New England's haze is sulfate, a chemical combination of sulfur and oxygen that is associated with acid rain.

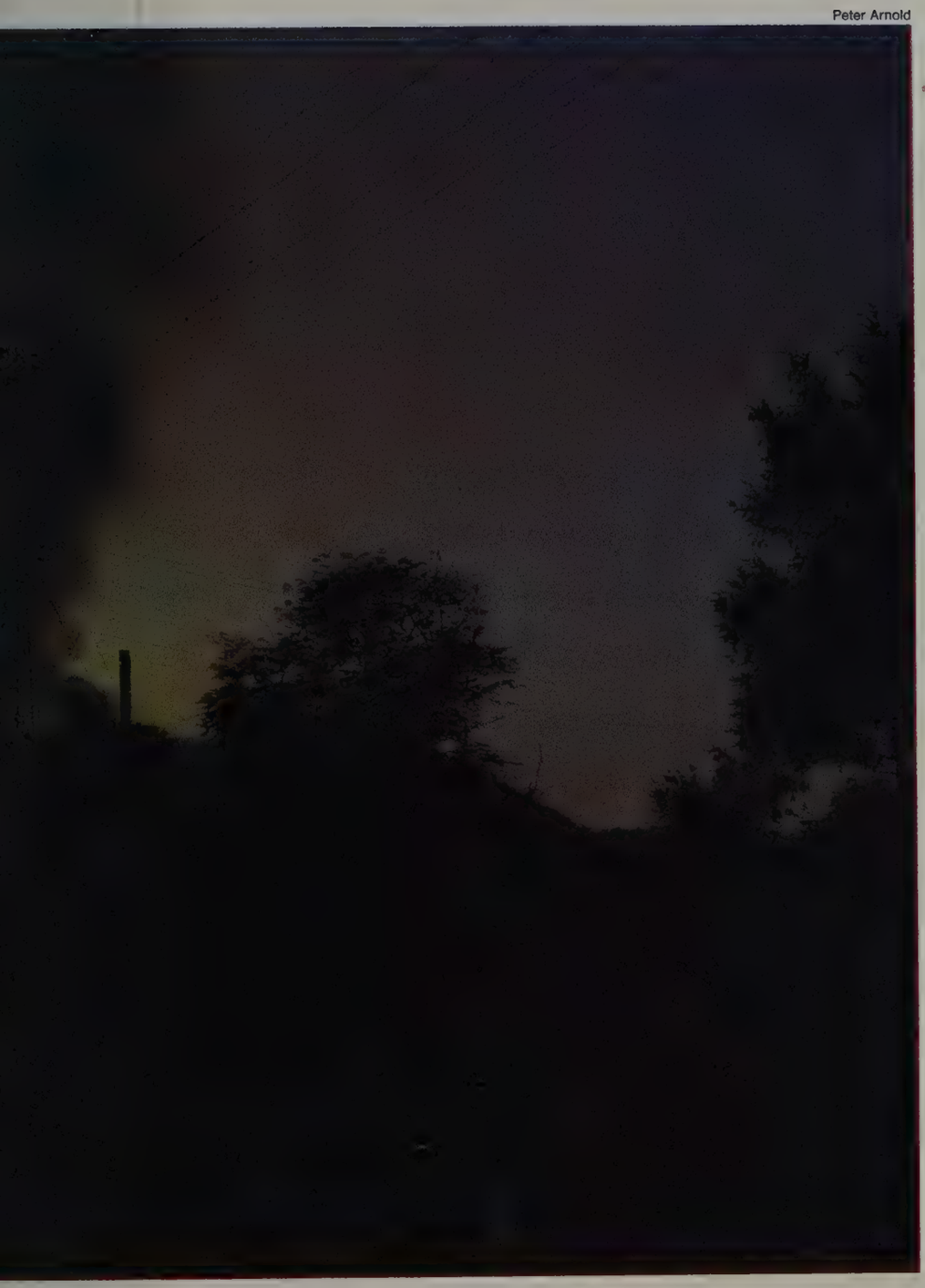
Haziness is the optical effect created by tiny particles of pollutants, collectively called aerosol, suspended in the atmosphere. Typical aerosol particles, with a 0.1–10 micrometer radius (1 micrometer equals 0.00004 inch), are so small that they can float in the atmosphere for several days. Carried by the wind, they may travel hundreds or thousands of miles from their points of origin before being washed out by rain or falling to the earth. Under very dry conditions—as in deserts, the Arctic during winter, or the upper atmosphere—particles can be airborne for weeks or even months.

Because particles can move so far, determining the sources of regional haze is a knotty problem. At any moment, the aerosol at a given site can be a complex mixture of materials from a variety of distant and local sources. Separating the mixture into its component parts has challenged scientific minds for a decade.

An obvious approach to pinpointing the origins of pollutants is to trace parcels of air backward in time by plotting past wind speeds and directions from weather maps and other recoverable information. But this method is severely limited because it cannot tell us which portions of the final mix come from which sources along the same pathway. Consider, for example, the common southwesterly winds of summer. Before reaching a site in New England, this air may have passed over the southeastern states, the mid-Atlantic states, and the heavily populated, almost continuously urban area that stretches up the east coast from Washington, D.C., to Boston. Air-mass trajectories alone say little about the relative influences of each of these areas on the final haze in New England. Chemical analysis of the smog, however, can be very helpful. As it happens, pollution aerosols emitted in the coastal Northeast have a quite different chemical composition from those emitted in the interior of the United States. Analysis of these chemical differences allows us to distinguish local aerosols from distantly derived ones.

A major key to the chemical differences in regional aerosols is the type of fuel burned to generate electricity. Along the east coast, utility companies burn heavy residual oil, the product that is left over after the lighter fractions of crude o are removed to make gasoline, kerosen and diesel and jet fuel. Relatively litt residual oil is used inland, however, b cause it is so viscous that it must be ke heated if shipped from east coast refi eries and ports. Therefore, most inlan power plants burn coal.

Residual oil is rich in vanadium an nickel, and when burned, releases enoug of those elements to give the local atm



Peter Arnold

sphere a distinctive stamp. Coal, in contrast, is relatively free of vanadium and nickel but rich in such elements as selenium and arsenic. (None of these characteristic features exist in isolation, however; each is distinctive only in comparison with other elements.)

Other differences between east coast and interior pollutants are related to population density. The aerosol in heavily populated regions has its own characteristic combination of elements, including zinc and antimony from the incineration of refuse and lead from automobile exhaust. These elements are higher in urban aerosols than in rural and remote aerosols and can serve as additional markers that differentiate coastal and interior aerosol pollution.

We deal with all these regional differences simultaneously in a system for tracing regional elements that we have been developing since about 1980. Applying that system to New England, we have found that of the approximately twenty elements that are pollutants, seven—arsenic, antimony, selenium, zinc, indium, manganese, and vanadium—are particularly useful for tracing purposes. In time, other elements are sure to be added to the system; we have already begun to investigate nine other potential tracer elements.

The tracer system was originally developed to enable us to understand the sources and transport of pollution aerosol in the Arctic. That application has been very successful and was described two years ago in *Natural History* ("Who's Polluting the Arctic?" May 1984). To determine the major chemical "signatures" of regional pollution in eastern North America, we sampled aerosol in the Northeast and Midwest. From numerous samples taken at various locations, among them Narragansett, Rhode Island; Underhill, Vermont; Allegheny Mountain, Pennsylvania; and Akron, Ohio, we were able to identify the local components and found that there are at least five different regional signatures: two along the east coast, two in the Midwest, and one from the nonferrous smelters in southern Ontario and Quebec. Statistical analysis shows that for all practical purposes these signatures differ from one another.

The mathematics of fitting the five signatures to a sample is quite involved, and the results are hard to verify. But there is abundant circumstantial evidence that our apportionments of chemicals are meaningful. We analyze a season of daily aerosol samples from a site, calculate the proportions of regional pollutants in each sample, display those quantities in the form of a graph, and then look for associations between the aerosol patterns and weather patterns. We have found that in most cases the chemical and meteorological evidence corroborate each other in terms of where the pollution is coming from on any given day.

We concluded that some locally derived aerosol is always present, to which distantly generated aerosol is occasionally added. About half the time the aerosol is predominantly local and half the time a

sizable amount has come from distant midwestern sources. That makes good common sense because Narragansett is surrounded by northeastern sources of pollution and can therefore never escape their influence. Midwestern sources, though, can be cut off entirely by nothing more than winds coming from a different direction. Even the durations of the midwestern surges, or pulses, of aerosols—commonly between two and four days—make sense: high- and low-pressure areas, which control the patterns of large-scale airflow to Narragansett, also fluctuate in periods of a few days to one week.

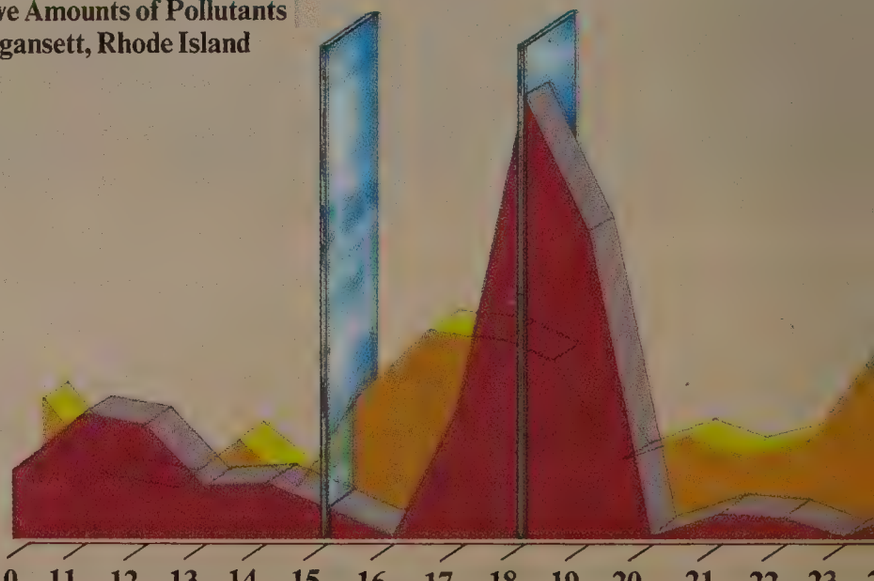
Through a cooperative program with Rich Poirot of the Vermont Agency of Environmental Conservation, we have received samples from Underhill, Vermont, for the same periods as those from Narragansett: We found that most major pulses of midwestern aerosol appear and disappear within a day or two of the same time at Narragansett and Underhill and that the arrival of pulses from the Canadian smelters are just as closely coordinated. From this near-simultaneity we infer both that region-wide measurements are valid and that chemical changes in the northeastern atmosphere are synchronized with regional, rather than local, events. In general, when the polluting aerosol at Narragansett (or Underhill) is primarily of local origin, the air is either locally stagnant or moving into New England from the north. When a distinctly midwestern aerosol is superimposed on the local pollution, there is large-scale airflow from the Midwest.

We took daily local samples at given sites and averaged them over three-month periods, and we have been reassured to find that our average apportionments of pollution aerosol in New England vary little from site to site and from season to season.

Our findings at Narragansett and Underhill were as follows. Most—60 to 80 percent by weight—of the zinc and manganese in Narrangansett air was attributable to local northeastern sources, with the remainder coming from the Midwest. (These elements are present in about equal concentrations in distant and local aerosols, so that one might expect nearby sources to supply the greater share.) Also consistent with expectation, the northeastern sources accounted for more than 90 percent of the oil-combustion elements, such as vanadium, which are relatively uncommon in midwestern emissions. Canada supplied our study sites with about 50 percent of their arsenic and 30 percent of their indium—both elements particularly rich in emissions from Canadian smelters. Interestingly, half or more of the sulfur

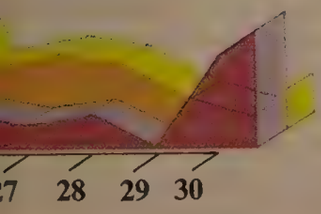
Pollutant Pathways

Relative Amounts of Pollutants
Narragansett, Rhode Island



e pollutants in the air over Narragansett, Rhode Island, mainly local in origin mixed with particles from the Midwest? It depends upon the weather. On July 1982, an air mass stagnated over much of the Northeast, blocking the flow of (maroon arrow) from the Midwest. On that day, locally generated pollutants outweighed distant contributions. Three days later, a low-pressure system yanced eastward across southern Canada, deforming a high-pressure system er the South Atlantic. A stream of air flowed between the systems, bringing a ong influx of midwestern pollutants to Narragansett.

Midwestern pollutants come to the Northeast in surges. Between July 10 and July 30, 1982, locally generated pollution was fairly constant in Narragansett, while midwestern aerosols arrived in one major pulse, peaking on July 18. Two days later, after a cold front had passed through the area, midwestern pollutants were virtually absent from Narragansett air.



Illustrations by Susan M. Johnston

and selenium measured at the Narragansett study site was traceable to the midwestern sources. This is as high a contribution from the Midwest as we find for any element.

Of these apportionments, sulfate is of greatest current importance because it is the largest contributor to acid rain. Since the Midwest emits ten times as much sulfur dioxide, the parent of sulfate, as the Northeast does, the roughly 50/50 split we found between local and distant sources of sulfate means that the amount of distant midwestern aerosols has been reduced in the northeastern atmosphere by a factor of ten. We think that this level of reduction, large as it might seem at first glance, is plausible. Recall that about half the time, there is no midwestern aerosol in Narragansett. The distance between the nearby sources and those 600 to 800 miles away in the Midwest could easily account for another factor of five or so. Computer models for the long-range transport of sulfur, which include, among other variables, detailed meteorological information, also tend to yield a reduction of roughly ten for those distant sources.

We believe that our technique for determining the geographical derivations of chemical pollutants is significant because before we applied it to acid rain precursors in New England, the general assumption was that the pollutants had been generated solely in the Midwest. With the new knowledge that some local sources are *always* present, a good start can be made in controlling the original pollution.

In spite of the amount of work that has gone into developing and applying our regional elemental tracer technique, and the successes it has produced, we know that it is only a beginning. More chemical elements and regional signatures are needed, as well as studies at a greater number of receptors in the Northeast. The Southeast, where emissions of sulfur dioxide have been increasing faster than in the rest of the country, should also be studied, along with Mississippi River Valley emissions. Most importantly, the tracer technique needs to be extended to rain and snow themselves so that sources of acid rain can be studied directly. Since it rains only about 5 percent of the time in the northeastern United States, layering of the atmosphere and the selective trajectories of rainstorms could easily lead to sources of acid rain that differ considerably from sources of surface aerosol. Encouraged by the success we have had so far with our chemical tracer system, we see no reason why the same system cannot be applied to the contaminants in rain with equal success. □

Animal Rights and Wrongs

by Matt Cartmill

Animals whom we have made our slaves we do not like to consider our equals.
—Charles Darwin

There is a faint smell of fear these days in the corridors of science. You can catch whiffs of it in all sorts of places: in editorials in *Nature,* in the angry resolutions crowding the agendas of scientific meetings, in the reams of P.R. releases streaming out of medical centers. Everywhere you turn, biomedical researchers are starting to padlock their dog kennels and throw up defenses against the threat of the animal-rights movement.

The threat is real. Labs from England to Hawaii have been broken into by animal-liberation guerrillas and ransacked of animals and records. One such break-in at the University of Pennsylvania turned up videotapes of monkey injuries that put an end to the lab's federal funding (with a little help from an animal-rights sit-in last year at the National Institutes of Health). New NIH guidelines for the treatment of lab animals went into effect this January, and in February, Columbia University had $75 million in grant funds cut off for violating those guidelines. One Maryland researcher was convicted of breaking state anticruelty laws after a court-sponsored raid on his lab. Bills placing ever stricter curbs on animal experimentation are popping up in legislatures all over the map. No wonder the scientists are starting to peer nervously out their windows at all those people with the placards.

THE CASE FOR ANIMAL EXPERIMENTATION, by Michael Allen Fox. *The University of California Press, $24.95; 262 pp.*

What few scientists yet realize is that this time the antivivisectionists are pushing some impressive philosophical artillery up to the barricades, and that the biomedical research establishment is in danger of getting blown away philosophically, as well as politically. Today's animal-rights activism has its roots in the Hunt Saboteurs Association, whose members have been running around Britain since 1964 sowing hunt fields with dog food, false scents, and roadblocks (and getting beaten up by furious hunters). But the activists' motives remained largely sentimental and intuitive until 1975. In that year, Australian philosopher Peter Singer published his book *Animal Liberation,* which has stood ever since at the heart of animal-rights theory.

Arguing along the same lines as Jeremy Bentham and other utilitarian philosophers, Singer urged that there is no reason that a boundary between species should be taken as necessarily relevant to morality. Man's unique capacities, said Singer, give us grounds for treating people and beasts differently in some ways; but not all human beings have human capacities. Many people—infants, the brain-damaged, the congenitally defective—are as unreflective and inarticulate as any beasts. Yet we shrink from using such people for drug testing, lampshades, or pot roast, which is how we use animals. Singer denounced this as mere prejudice, akin to a bias against black people or women. If it is wrong to put defective human beings to such uses, it must be equally wrong in the case of equally sentient animals. Singer concluded that it is wrong in both cases for the same utilitarian reason: the benefits derived from these uses are generally outweighed by the suffering they cause.

Confronted with these conclusions, most scientists dismiss them without thought. A fairly typical outburst was that of James Watson, codiscoverer of the DNA helix, who said in a 1985 speech, "There is a debate now as to what is the right of a mouse. Why are we wasting time in Washington with taking seriously this business? . . . This is complete and absolute craziness." Watson also charged that the reason there are so many "silly" federal constraints on biological research is that "the White House receives its advice from people who know something about physics or chemistry. The person in charge of biology is either a woman or unimportant." Singer's charges of unthinking prejudice couldn't have been more neatly illustrated if he had invented Watson for the occasion.

So long as the defense of animal experimentation is left to researchers who think they are protecting science against lunatic sentimentality, that defense will continue to misfire. The animal-rights philosophers have at least as much justification for their view of themselves as the truly scientific parties who are struggling to bring home the implications of evolutionary theory. They regard their moral stance as a natural corollary of Darwin's claim that "there is no fundamental difference between man and the higher mammals in their mental faculties"—a claim that receives a good deal of support from some of the very researchers targeted by the animal-rights movement. If the researchers hope to unhorse the theoreticians of that movement, they are going to have to rely on philosophy, not biology, to do the job.

In *The Case for Animal Experimentation,* the Canadian philosopher Michael A. Fox comes to the researchers' defense. Fox spends a third of his book establishing that animal experimentation is motivated by a thirst for knowledge, not for blood, and that we can learn many useful and important things from it. All this is true and is a relevant reply to the sort of antivivisectionist who thinks that scientists get sadistic pleasure from doing nasty things to rats. Unfortunately, few of those people are going to read this book.

Fox's more subtle and interesting arguments address the philosophers who hold that animal experimentation, although useful, is nonetheless wrong. There are two schools of these people. Utilitarians like Singer allow that injurious research on animals (or on humans) may sometimes be justified by potential gains in

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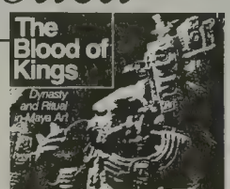

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human (or animal) welfare but insist that most actual experimentation involves too much suffering for too little gain. The rights advocates, led by the American philosopher Tom Regan, hold that all such research, however profitable, violates the moral rights of the experimental subjects. Those rights are theoretical entities (rather like the physicists' quarks) that are postulated to provide logical support for fundamental but intuitive moral judgments—in this particular case, our judgments that cruelty to animals and the use of unintelligent humans as guinea pigs are immoral.

Fox agrees with those judgments, but he wants to find support for them without leaving any room for animal rights or for weighing animals' interests on the same scale as our own. His first move is to tell us that people differ profoundly from other animals in being *autonomous agents*. This means that only people have "the ability . . . to generate a life plan in relation to which [they] guide their lives as a whole and monitor and evaluate the varying conditions of their lives." I suppose I must be as autonomous as anyone, but I don't know whether I could do all that without some help from Dr. Fox. Fox succumbs here to the occupational disease of thinking something characteristic of humanity when it is really characteristic of philosophy professors. His definition of autonomy is crucial to his argument, for animals' inability to plan and assess their lives as a whole tells Fox that they do not "have their own lives to lead." They are not really individuals. Their lives and pleasures "are not valuable to them because animals are incapable of judging and articulating that they are." Therefore animal lives have value "only in the instrumental sense, that is, in relation to the uses to which we put them"—including, of course, medical experiments.

Fox thinks it nonsensical to say that animals have moral rights, which "are functions of the mutual recognition that occurs within a social group of autonomous beings." Such a group constitutes a "moral community," defined as "a group of beings . . . who consider themselves bound to observe certain rules of conduct in relation to one another because of their mutual likeness," and who grant rights to each other as "a declaration of non-intervention in the self-governing lives of others." Here we stand in the venerable presence of the social contract, made famous by Locke and Rousseau but given up by most later philosophers as a misleading fiction. But the social-contract theory suits Fox's aims perfectly. Since beasts can't join a moral community or enter into contracts, they have no rights and we can
pretty much as we like with them: Q.E.

But what about defective people w
don't meet Fox's criterion of autonom
Fox tries to stretch things to bring the
into the fold and at once starts trippi
over himself. His basic argument
"There, but for the grace of God, go I."
might have been born defective; my chi
may be born defective; accident or disea
may leave me defective; therefore, "cha
ity, benevolence, humaneness, and pr
dence" alike prompt me to grant rights
such poor creatures. This argument w
not apply to animals, since it makes
sense to substitute, say, "a hamster" f
the word *defective* in the preceding se
tence. The trouble with this is that it do
make sense to substitute "dead"—but th
conclusion then does not follow. (We w
all be cadavers some day, but that doesn
mean that we should agitate for cadav
rights.) Fox is making the hidden assum
tion that I can know what it would be lik
to be a defective person used in medic
experiments, and that I would not like
Stripped of its interesting but morally i
relevant considerations of mere prudenc
his argument really reduces to the golde
rule. Once we see this, it is hard to resi
extending the principle to animals. Fo
objects that it makes no sense to as
"How would *you* like to be an experime
tal animal?" because nobody can kno
what it would be like to belong to a diffe
ent species; but the same objection go
for human defectives. The mental life of
healthy chimpanzee is probably more a
cessible to us than that of, say, a baby bo
missing large parts of its brain.

If (as Fox thinks) we have no duties
animals and their lives have only instr
mental value, then why should we deplo
cruelty to animals? Why prohibit bea
baiting and other such robust amus
ments? Why anesthetize vivisected an
mals, instead of just paralyzing them wit
curare to stop their writhing and yelpin
(as many nineteenth-century researche
preferred to do)? Fox is too decent to fo
low his logic to its repellent conclusio
here, and he piles up one specious argu
ment after another in his search for loo
holes. He begins with a string of non sequ
turs in which "ought" is inferred fro
"is"—what philosophers call the natura
istic fallacy. Cruelty to animals, he su
gests, is wrong because we feel empath
for animals, appreciate our evolutionar
continuity with them, and have an "ec
logical awareness" of "our unity with a
organisms."

This is true and generous, but irrel
vant. Because we *do* feel empathy doesn
mean that we *ought* to, as Fox himself

first to insist when lab animals are in stion. And why should our evolution- theories have implications for our tment of animals? Surely it must be ıe property of the beasts, not their ori- that makes it wrong to abuse them. (Is rbaiting all right if creationism is ?) Fox next tries to argue that cruelty wrong because the cruel individual mages his moral character" and "sinks ow some ideal standard of behavior"— ich says only that mistreating animals vrong because it is immoral. This gets no further. Finally, Fox caves in and ıcedes that we have "a kind of obliga- ı . . . analogous to, but not identical h, a strict moral principle" to treat ani- ls humanely. The exact difference be- een a kind of moral principle and a real e isn't explained, but presumably if we ve a kind of obligation not to mistreat mals, then they have a kind of right not be mistreated. This takes us right back someplace kind of like square one.

Fox has no difficulty showing that giv- up animal experimentation would ve adverse effects on science and tech- ogy. Perhaps that is all that need be d for practical purposes. But it is not lly the question at issue, unless we want equate morality with intelligent self- erest. And the price for doing that is gh, for it leaves us with no reason for ploring such perfectly prudent old prac- es as curarizing experimental animals d whipping pigs to death to enhance the vor of their hams. The logical snarls at Fox gets into when he tries to escape m this bind suggest that the prevailing rality he defends may be just as inco- rent as the animal-rights philosophers ve been claiming. No doubt a moral stinction of some sort has to be drawn tween people and animals per se; rescu- g a human baby from a wolf has got to more imperative than rescuing a rabbit m a wolf or morality becomes a joke. t so far no one has come up with a asonable and consistent set of principles at justify the moral weight we place on e boundary between our species and oth- s. The nature and implications of the fferences between people and other ani- als is a subject about which biologists d social scientists have a great deal to y. Perhaps, even as we barricade our bs and listen for the footsteps of the nimal Liberation Front on the stairs, we ientists should thank the animal-rights ilosophers for raising our theoretical estions to a plane of the utmost practi- l urgency.

Matt Cartmill is professor of anatomy and anthropology at Duke University.

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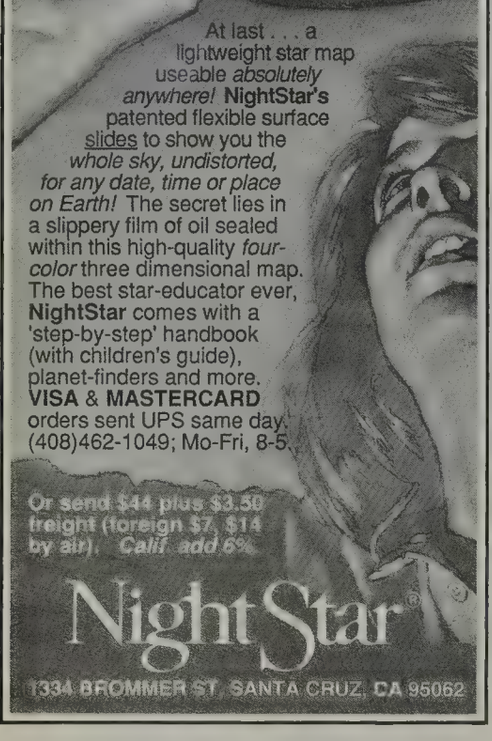

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The Planet Chase

by Thomas D. Nicholson

You will be hard put to find a time of night this month when you can't see a good display of planets. From sundown, with Venus blinking in the twilight, until dawn, when Mars and Jupiter vie in outshining one another, you can't miss. Now that Mars is near opposition, it rises very nearly at sunset and doesn't set until daybreak. Its great brightness during this "favorable" opposition and its easily discerned reddish color make it stand out. It competes with Venus after dark (Venus takes the prize for brightness) and with Jupiter from midnight on, but it cannot be mistaken for either one.

The early evening sky finds Venus at its post in the west, while Mars comes out of the growing darkness in the east. Within a few hours Venus is down, but Mars moves up into the southeast. Ahead of it, Saturn, Antares, Spica, and Regulus, all first-magnitude objects, stretch up the sky as Mars's herald. Behind Mars and below the eastern horizon, Jupiter lurks in Pisces, then suddenly appears in the east after midnight and joins the westward march of the planets and stars. By dawn, the leaders have dipped below the horizon in the west, and only Mars and Jupiter remain, with ruddy Mars low in the west and brighter Jupiter high in the south.

Events in the calendar below are given in local times unless otherwise indicated.

July 1: The moon begins the month in Aries, the constellation that was once host to the vernal equinox (still sometimes called "First Point of Aries"). It's only a sliver of a moon, though, barely visible as dawn creeps up behind it.

July 4: The moon will be at apogee (farthest from the earth) but will probal go unnoticed since it is so close to bei new moon.

July 5: The sun may be hot and the d scorching, but be grateful that the earth at aphelion (greatest distance from t sun). Imagine how hot it would be if t earth were even closer to the sun.

July 6: Five minutes before midnig tonight (11:55 P.M., EST) the new mo comes along right on schedule, and a n cycle of lunar phases begins.

July 8: Just as Mercury begins its ret grade (westerly) motion today, the mo passes it. With the sun so close, of cour we can't see either.

July 10: Mars will be opposite the s tonight, but it will not be nearest the ea for a few more days. The slender cresc moon joins Venus in the evening. It do not get as close as we might like, but it w be attractive enough. Look toward t eastern sky (opposite Venus) where y can find Mars rising. The star near Ven is Regulus, in Leo.

July 12: The autumnal equinox, locat about midway between Spica (in Virgo the left) and Regulus (to the right in Le is very near this evening's moon.

July 13: Jupiter shifts celestial ge today from its normal (easterly) motion retrograde (westerly). When that occu opposition and the evening configurati of the planet aren't far behind.

July 14: First-quarter moon at 3:10 P.M EST, is just above Spica, Virgo's brig star, in the south at dusk. Both set abo midnight.

July 15–16: The moon waxes larger a stays later each night as it works ea through Libra, moving away from Spi

Celestial Events

vard Saturn and Antares to its left. rs is nearest the earth on the 16th.

July 17: The moon slips through the gap tween Saturn (above) and Antares (be-) on its way through Scorpius. Both net and star should be easy to see de- te the light scattered around the gib- us moon. The moon doesn't quite make past Antares, however. At about 11:00 ., EST, approximately when the moon d star set over the eastern United ates, the moon covers the star. The oc- tation will be more readily seen farther st (in earlier time zones), where the jects will be higher.

July 18–21: The moon and Mars are on ge in Sagittarius. Perigee moon earest the earth) is on the 19th, with the on in the Teapot's lid. Full moon is at 0 A.M., EST, on the 21st, just before the on enters Capricornus. Mars, now vir- ally at its brightest, is easily seen each ght through the moon's glare.

July 22: The moon rises in Capricornus out 9:00 P.M. Jupiter follows it up at out 11:00 P.M. Any time later, look for a lumn of bright objects arching across e sky from Jupiter to the west (right). is celestial parade leads off with the on followed by Mars, then passes Sat- n and Antares to Spica, and ends with egulus in the west before it disappears om view. These bodies approximately ace out the plane of the ecliptic (the rth's orbit) around the sun.

July 23: Mercury, at inferior conjunc- n (between the earth and the sun), be- mes a morning star.

July 24–25: Jupiter and the moon rise gether late at night. The moon then oves slowly to the left beneath the planet

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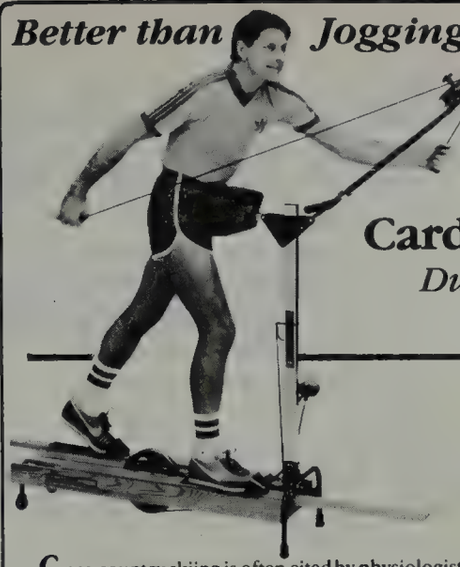

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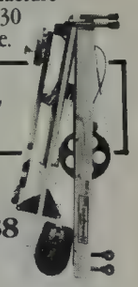

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as they work westerly together. The two are closest at about 1:00 A.M. on the 25th.

July 28: Last-quarter moon (at 10:34 A.M., EST) is in Aries, where the moon started out this month, but this time it is several days later in phase as a thin, waning crescent. Hamal and Sheratan are the two stars above the moon on the morning of the 28th.

July 31: The moon is again at apogee, this time in Taurus. It rises up the dawn sky near the Hyades, the V-shaped cluster that marks the Bull's "face." □

The summer Sky Map identifies constellations and stars for the months of July, August, and September from latitude 40° north at the evening hours given below. To use the map, hold it vertically in front of you with south (S) at the bottom, and match the lower half of the map with the stars you see facing south. As you face in other directions, roll the map to bring the corresponding compass direction to the bottom of the map.

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Lost and Found Traditions

by Laurie Nadel

Ralph T. Coe, curator of the exhibition Lost and Found Traditions: Native American Indian Art 1965–1985, spent nearly a decade traveling into the forgotten reaches of North America in search of modern American Indian artists. In this quest, he crossed the length and breadth of North America, from Labrador to southern Alaska, from Florida to California, visiting most of the fifty states and several Canadian provinces. Of North America's approximately three hundred to four hundred extant Indian tribal groups—estimates vary with definitions—Coe visited about seventy and contacted more than one hundred in all.

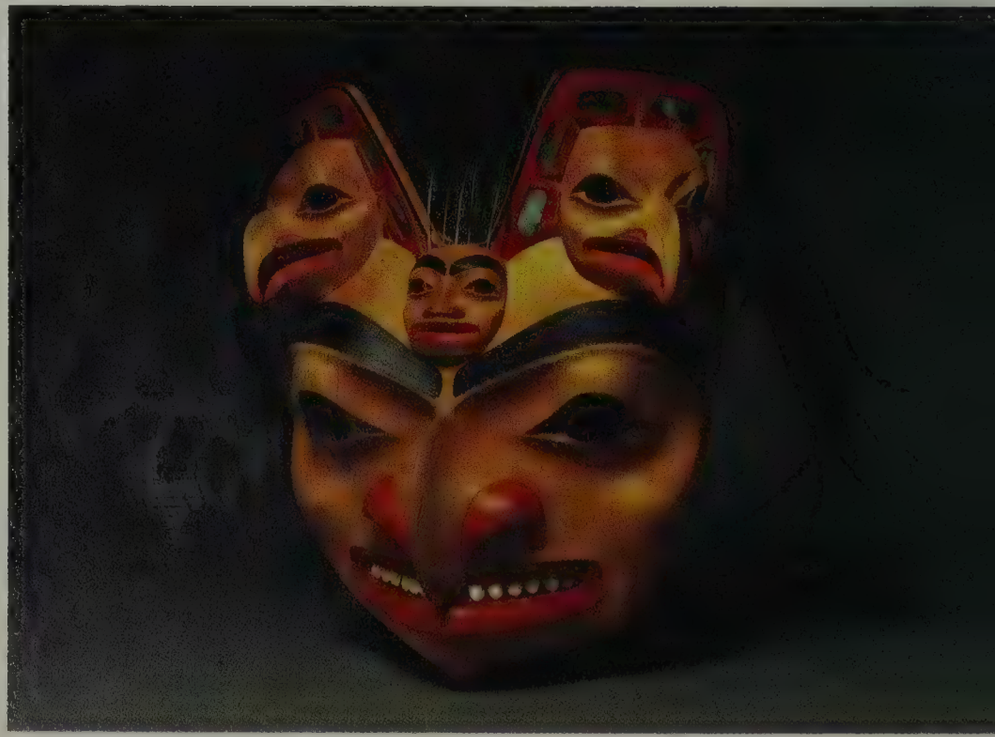
For Lost and Found Traditions, he ultimately selected 383 objects by more than 275 contemporary artists, all working with traditional techniques and often with traditional materials—quills, beads, bone, hides, fur, wood, and clay. The exhibits range from the massive, thirty-five-foot-high traditional totem pole of the Nishga, the first modern pole ever to be lent by this Northwest Coast tribal group, to a modest awl with a cow-tendon handle made by a Rosebud Sioux elder from South Dakota. As a whole, the exhibition demonstrates that contemporary American Indians continue to fashion traditional objects for utilitarian, decorative, or ceremonial use within their tribes and communities. For perhaps the first time, the show brings to the outside world objects that were not made merely for sale to tourists or white traders.

The main importance of the exhibition is that it makes it possible for white (and mainstream minority) Americans to see and understand North American cultures that are otherwise hidden from, or off-limits to, them. Coe feels the show is also a symbol of hope for the Indians themselves, an affirmation of their artistic heritage. "This way," Coe says, "they can see that despite everything that happened to them, they are still living cultures."

A trustee of the American Federation of Arts and a former director of the Nelson Atkins Museum of Art in Kansas City, Missouri, Ralph Coe's formal background lies in European art and ornithology. American Indian art began to attract him in the mid-1950s. In 1976, he was curator of the exhibition Sacred Circles, a sho organized by the Arts Council of Gre Britain. Coe says, "I met a lot of India demonstrators there and became co cerned that I, like many other American knew Indian art in a museum but didn connect that art with real people. Yet he they were. What did they think of a this?"

After a Kansas City showing of Sacre Circles, Coe recounts, he "started snea ing away to Osage dances and leading double life. Indians are very reticent ar guard their cultures very carefully. The don't like outsiders bursting in on the and I don't blame them." Coe's goal w to locate and purchase or, in a few case negotiate the loan of works made by co temporary American Indian artists. Th artists whose work Coe chose were n necessarily those best known to traders

Lost and Found Traditions: Native American Art 1965–1985 is now at the American Museum of Natural History and will remain on exhibit until October 5, 1986. In 1987 and 1988, it will travel to Portland, Oregon; Saint Paul, Minnesota; Anchorage, Alaska; Cedar Rapids, Iowa; Albuquerque, New Mexico; and Los Angeles, California.



A modern mask reflects the artist's Tlingit and Tahltan heritage. Bobby Hanss

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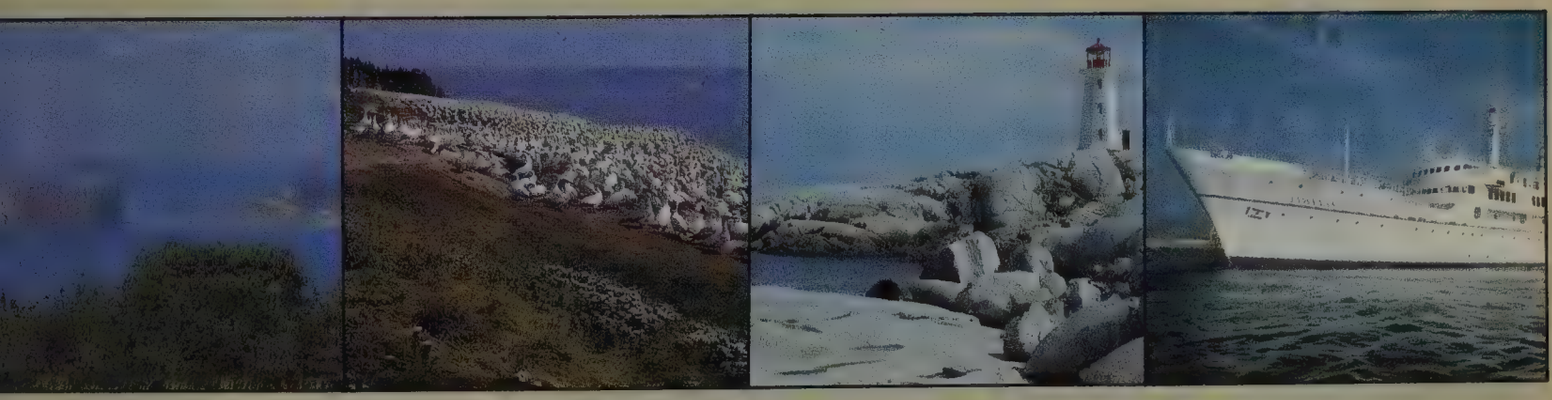

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collectors but those whom he thought were promising or outstanding. "I wasn't going for just what white people want for the white-oriented market," Coe explained. "I asked myself, 'What is the nature of the cycle of losing and finding traditions? Do these people deserve recognition or is too much of their art lost? I want to find out.' " After a period of traveling that included treks into Alaska and to the remote northwest regions of Canada, Coe knew that "no matter how much was lost, if I was patient, I could build a whole corpus of work." Formalization of the project came in 1977 when the American Federation of Arts (AFA) committed itself to the undertaking. As organizers of the exhibition, the AFA then obtained funding from the American Can Company Foundation, the National Endowment for the Arts, and the Sacred Circle Fund.

Beaded sneakers, a Sioux fashion since the mid-1970s

Bobby Hansson

The goals of the project proved difficult to meet. Coe had to travel "right off the map into the wilderness. I was a loner in Indian country." In the course of his search for Indian artists, Coe experienced not only physical danger, when a brown bear attacked the trailer he was camping in, but also disappointment. On more than one occasion a promised work had not been completed because the artist's "hands were cold" (a phrase that might signify anything from an unforeseen interruption to an attack of arthritis). On another, an artisan did not want to meet him after he had journeyed to her far-off community more than once for that purpose. But for Coe, absorbing how Indians communicate was as important a part of his work as acquiring the objects he had set out to find. "Nothing happens on demand in the Indian world," Coe says. "I learned never to ask direct questions. I always left things open." Verbal communication became less necessary as Coe came to sense a strong intuitive presence in many of the Indian communities. "They never said anything but I felt they were studying me. I sensed they knew things about me that I didn't know. Sometimes they knew when I was returning, even though I had not phoned ahead to tell them. One of my colleagues arrived at an Indian home to find them setting the table for him." Once, when Coe returned to British Columbia after a long absence, an Indian woman told him, "I saved you a cake because I knew you would come."

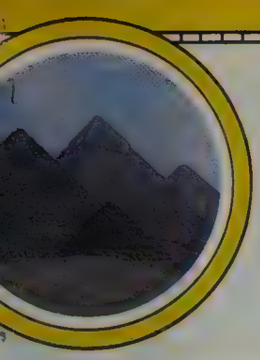
The Indian concept of time proved far more fluid than what Coe was used to, and deadlines for the project had to be adjusted accordingly. "Indians don't think in the same chronology we do," he observed. "They recognize time as a tool. Consequently the show developed organically, stretching out in four directions, Indian style. Lost and found is part of a cycle that runs through Indian life and always was. It is we white people who need beginning and ending dates."

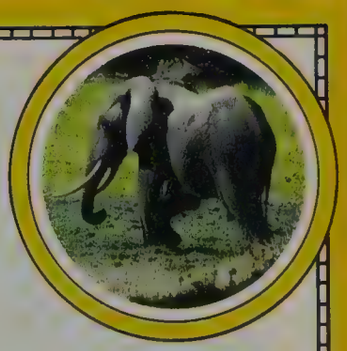
Kerfed (steam-bent) box by Makah carver Greg Colfax

Ralph T. Coe

Slipping in and out of Indian communities, leaving and reentering what Coe calls Yuppie America, has not been without its price. He has at times felt estranged from old friends and has experienced the frustration that comes of trying to explain to the unhearing and uncaring where he has just been. "You can never really come back once you have experienced Indian spirituality and their sense of sharing," he said. "I only wanted to visit on their terms, not study or put them in a bottle." Although he wants to return to Indian country once the show opens, Coe does not intend to live there. "There is a satirical name for so-called white Indians. It's *wannabe,* as in 'I wannabe an Indian.' Well, I don't wannabe a *wannabe.* I feel comfortable in the Indian world and I miss it, but there are many things I feel I should not be a party to."

If there is one object in Lost and Found Traditions that, for Coe, symbolizes not only his search but the exhibit itself, it is the kerfed box by Makah carver Greg Colfax. Kerfing is a woodworking method in which wood is incised and bent, sometimes with steam, in order to convert a





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single board into a box. Colfax's box is sometimes referred to as a steam-bent box. The Northwest Coast Indians use kerfed boxes to hold food, clothing, and possessions. But in the northern reaches of British Columbia, larger containers are sometimes used to hold human remains. Greg Colfax's box, however, is not utilitarian but ceremonial; he deliberately used a traditional form to make a statement for the show.

Colfax, a carver in his early thirties, became intrigued by Coe's project because he, too, has been considering the role of tradition in his own life and the life of the Makah. The back of his box shows a man with his eyes unfocused; according to Coe, this denotes a man who cannot see because he has lost his traditions. Above the man is the tail of a whale; around him, an octopus tentacle. They symbolize the sea life that is the chief spiritual focus and economic livelihood of the Makah. The back of the box represents the man's purposeless journey. On the front panel, he is shown being adopted by the spirit guide and tutorial entity of the Makah tribe, the Great Wolf Spirit, whose head protrudes from the front of the box. As the man rides on the wolf's back, a metaphor for the four-day Makah wolf ceremony (a major ritual that preserves tribal unity), he comes to understand his traditions. He is depicted with a seeing face on one side panel; on the other side panel, the wolf's legs symbolize the man's journey with the Great Wolf Spirit, a journey of understanding and insight. The panel showing the man's seeing face also depicts the image of a dog, symbolic of the man's being welcomed back by his people on the beach.

Because of its many levels of symbolism, Coe calls the kerfed box "a metapho of Makah civilization." He cautions, however, that "you have to have the eyes t look. Many Americans don't. It is not advertising art, it is not literal."

Coe is concerned that the public will no view the box and the other objects as par of a vital artistic heritage. He worries tha the living aspect of the show will b shelved, that once the objects are cata loged and explained, the process of learning from them will be over. "Colfax's bo is a metaphorical reality," he said. "It i the distillation of images that form th Indian psyche. It's there, and its being there is a miracle. Because of all we've done to these people, it's a miracle. Ou there, in Indian country, they're thinking and thinking about this all the time They've never really lost their traditions In fact, they're coming back to them stronger all the time."

Laurie Nadel, a writer for CBS News, ha written articles on the arts for severa magazines, including Signature, Islands *and* FMR.

At the American Museum

At the Planetarium

Wonderful Sky, the Planetarium's special show for preschoolers, is back at the Sky Theater. This show takes children on a journey of exploration and encourages them to sing along as they learn about weather, rainbows, sunsets, distant stars, changes of the moon, and other objects in the sky. Show times for *Wonderful Sky* are: Saturday, July 12, and Saturday, August 2, at 10:00 A.M. and noon. For additional information and reservations call (212) 873-5714.

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Addressing Salad

How did vinegar and oil, mixed together, become applied to salad greens in the first place?

by Raymond Sokolov

"I am not ambitious of being thought an excellent cook, or those who set up, and value themselves for their skill in sauces; such as was Mithacus a culinary philosopher, and other eruditae gulae; who read Lectures of Hautgouts, like the Archestratus in Athenaeus: Tho' after what we find the Heroes did of old, and see them chining out the slaughter'd Ox, dressing the Meat, and do the Offices of both Cook and Butcher, (for so Homer represents Achilles himself, and the rest of those Illustrious Greeks) I say, after this, let none reproach our Sallet-Dresser, or disdain so clean, innocent, sweet, and Natural a quality; compar'd with the Shambles Filth and Nidor, Blood and Cruelty; whilst all the World were Eaters, and Composers of Sallets in its best and brightest Age."

John Evelyn
Acetaria (1699)

My sentiments exactly, Mr. Evelyn. I have felt this way ever since that day in 1971 when I joined the staff of the *New York Times*. I had been hired to be the paper's resident erudite gullet and apostle of *haut gout*. But in the personnel office, they hadn't heard about me and needed to give me a payroll classification.

"What will you be doing?" the young lady asked.

"Handling food," I replied.

So I matriculated as an N2: an assistant salad-handler in the company cafeteria, until I could prove a higher status.

Evelyn evinced no embarrassment about his involvement with salad. He kept his now famous diaries to his bosom but he published *Acetaria*. Today, its manner may seem overheated and donnish, but its matter couldn't be more modern. In the passage above, Evelyn is defending vegetarianism against the shambles of meat-eating; raw food against cooked (*nidor* is Latin for "cooking smells").

This much is preamble. Most of the book is an encyclopedic discussion of greens and other salad ingredients and not at all polemical. Modern readers may be surprised by some of the things that Evelyn put in salads—parsnips, for example—but by and large his salads are like our salads; even his salad dressing is recognizable as a vinaigrette (see recipe).

This should not really be cause for remark, given the title of Evelyn's book. As all of you remembered instantly, *acetaria* was Pliny's word for an oil-and-vinegar dressing. This link with the past is impressive, even profound, when examined closely. When I translated *acetaria* as "vinaigrette," I was translating loosely. The word really meant salad, although it was derived from the medium salad was dressed in. *Acetum* is Latin for "vinegar" (a sour liquid such as wine) and is a direct analogue of the word vinegar itself, which is a contraction of *vin aigre* (sour wine) in French. *Acetaria* is an adjectival form that literally means vinegary things, things mixed in vinegar.

But why should this term have become the word for salad instead of being applied more generally to the whole range of pickles and other foods flavored or preserved in vinegar? The dictionary says that *acetaria* was originally an adjective modifying *olera* (salad greens) and then came to stand for salad all by itself. But the dictionary also defines *acetaria* as "salad dressed with vinegar and oil." So when Pliny, and later Evelyn, wanted to say salad, the word they used did not explicitly mention greens or oil, both of which were so essential to the dish as to be automatically understood.

Something like this is involved in the word vinaigrette, which elliptically name a sauce for an ingredient that is not, i terms of quantity, its main ingredient. Th standard vinaigrette contains three par oil to one part vinegar. Proportions ma vary somewhat according to individua taste (and most people add other flavo ings as Evelyn does in the recipe below but every vinaigrette has much more oil i it than it does vinegar. Although som vinaigrettes contain no vinegar and ge their acid content from lemon juice, th sauce is still called vinaigrette, becaus the addition of an acid medium is wha distinguishes it from the fundamenta combination of greens and oil.

Since Roman times (and no doubt fro still earlier periods), people ate vegetable so customarily in an oil or fat medium tha they felt no need to talk about it. Then, a now, greens were cooked in oil or anima fat. What made this a salad was the add tion of vinegar. Whence *acetaria*, whenc vinaigrette.

Somewhere buried in the dawn of hu man cuisine, the addition of vinegar t vegetable had to do with preservation an the mildly culinary effect of vinegar o food. Anyone who has seen how the acid i lemon juice will "cook" seafood in sevich knows how this works. Vinegar has th same power. It is an acid byproduct o wine, bacterially produced and stabilize by a culture called vinegar mother. Vine gar is not just old, spoiled wine but ol wine that is deliberately "spoiled," inocu lated in fact.

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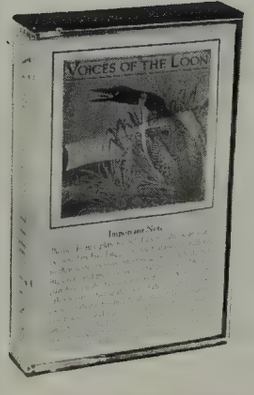

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which are really salad dressings disgui with spices or ketchup and used to tend ize and flavor meat and fish. (The prim dial connection between salads—n thought of as the epitome of fresh food and preservation is also strongly sugges by the word *salad,* so obviously connec with salt, the prime active ingredient that other great pickling medium, brin

But how did vinegar and oil come to mixed together in the first place? Wa an accident? No one knows, and we only speculate about the reason for popularity of the mixture.

It seems logical to assume that peo had oil and butter and animal fat bef they had vinegar. But once vinegar available to them, they would have about for something to dilute its streng They might have used water, but t didn't. Instead they proceeded to inv vinaigrette, an invention of genius wi viewed with hindsight. And the discov is most easily explained if we imagine t cooks already accustomed to mix greens with oil, decided to add a li vinegar to it, hoping thereby to liven the oil and to dilute the acridity of vinegar. Or the process may have wor in reverse. Early cooks may have tr preserving food in vinegar and then ad oil, already a common medium for vege bles, in order to dilute the vinegar make the food more palatable. Once t had tasted the mixture, they would h realized, as has everyone in the ensu centuries, that it was a delicious comb tion. From there it would have bee simple step from preserving vegetable vinaigrette to eating them fresh and with the same sauce. I like to think t the first cook who did this, and thus vented salad as we know it, cried out v joy. Or exclaimed, "Eureka!" if he or was a Greek.

To that first cook, however mod salad dressing would have been an inno tion, built on the far older, and more versal, practice of mixing vegetables v oils and fats. Here too preservation m have played a role. Fats and oils do serve food—think of goose preserved i own fat or olives cured in olive oil. To in southern Europe, sun-dried tomat cheese, and many other products are tled in oil for long keeping.

We have no obvious example of oil p ervation for salad greens, but we do h an entire vocabulary of dishes in whic green is either cooked in oil (bra radicchio, endive, or leeks, and saut escarole) or in which it is first sautéed oil or fat and then boiled until ten Either process may well have arisen means of preserving greens, which co

reheated or eaten as a cold salad. adays, and perhaps always, the us affinity of greens for oil or fat is to make people want to eat them r, even when the practical need to e greens has vanished with the nce of refrigeration and far-flung supply. Greens and fat are a splen- iring. Everyone who likes wilted n with bacon knows that, as do the more recherché fans of dandelion and bacon (see recipe), who may of this dish by its French name, *it au lard,* and associate it with ous dining abroad. But here at we have a whole menu of very un- ious related dishes. You will find n soul food menus—and you will em in Ernest Matthew Mickler's *White Trash Cooking* (The Jargon y, $11.95).

kler recently traveled throughout uth, collecting recipes from the f Big Reba Culpepper in Burnt Alabama, and Betty Mae Swilley in g Fork, Mississippi. "If someone me what sets White Trash cooking from other kinds of cooking," he "I would have to name three of the ients: saltmeat, cornmeal and mo- Every vegetable eaten is seasoned altmeat, bacon or ham."

kler's very first chapter is called tables 'n Meats." It has recipes for l greens, turnip greens, and mustard . For all of them, he starts by brown- tback, bacon or ham, then adds greens, cooks them until wilted, and finally adds water, cooking until the greens are tender. And, perhaps repeating one of the oldest dodges in culinary history, he seasons leftover collards with vinegar.

Mickler would find himself right at home in the most rarefied kitchens of France, where one of the hallmarks of the *nouvelle cuisine* is the *salade tiède,* an elaborate mixture of greens, fat, and (often) meat served warm.

For example, Michel Guérard serves a salad containing duck breast, dandelion greens, lamb's lettuce, and diced *foie gras,* dressed with oil, lemon juice, and the rendered fat from the *foie gras.* For his *salade gourmande*, he combines green beans, asparagus, salad greens, and *foie gras* with a vinaigrette.

Guérard thinks he has invented something. In *La Cuisine Gourmande* he burbles about the "surprising harmony between vinaigrette and *foie gras.*" Is he really surprised or is this an attempt to market an apparently weird food idea to a hidebound French audience? Or is the surprising part just the extravagance of treating *foie gras* in a manner traditional for other, less costly meats in southwest France where Guérard has his restaurant? Certainly Guérard's ingredients are fancy, but in concept we might as well be in Burnt Corn.

Raymond Sokolov is a writer whose special interests are the history and preparation of food.

John Evelyn's Salad Dressing

m *Acetaria,* reprinted in facsimile in 1982 by Prospect Books London)

. Take of clear and perfectly good Olive, three Parts; of sharpest Vine- sweetest of all Condiments), Lemon, ice of Orange, one Part; and therein teep some Slices of Horse-Radish, a little Salt: Some in a separate Vine- gently bruise a Pod of Guinny-Pep- straining both the Vinegars apart, to e Use of Either, or One alone, or of , as they best like; then add as much esbury or other Mustard grated, as lie upon an Half-Crown Piece: Beat mingle all these very well together; our not on the Oyl and Vinegar, 'till ediately before the Sallet is ready to aten: And then with the Yolk of two laid Eggs (boyl'd . . .) squash and se them all into mash with a Spoon; lastly, pour it all upon the Herbs d greens and other main ingredi-], stirring and mingling them 'till they well and thoroughly imbib'd; not for- ing the Sprinklings of Aromaticks and Flowers, . . . if you think fit, and garnishing the Dish with thin Slices of Horse-Radish, Red Beet, Berberries, &c.

Note, that the Liquids may be made more Acid as is most agreeable to your Taste.

Dandelion Salad

(*Pissenlit au Lard*)

1 pound young dandelion leaves
3 strips bacon, thickly cut if possible
3 tablespoons red wine vinegar

1. Wash the leaves, dry in a towel or salad spinner. Tear into pieces large enough to eat without cutting.
2. Cut the bacon into small cubes and cook in a skillet over medium heat until the bacon browns. Remove the bacon with a slotted spoon and add to the dandelion in a salad bowl.
3. Pour the vinegar into the skillet and cook with the rendered bacon fat until bubbles form. Then pour the mixture over the salad and toss lightly to distribute the dressing. Serve while still warm.

Yield: 3–4 servings

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School Bully

According to diver Dave Woodward, who photographed this confrontation between French grunts on a shallow coral reef off San Salvador Island in the Bahamas, it was the fish on the right that started it all and persisted in bullying schoolmates that came too near the purple sea fan over which he (or she) hovered.

While such mouth-to-mouth confrontations have often been observed in these common reef fish (their jaws are even jointed to allow for such extraordinary gaping) the exact nature of such disputes is still not understood. Although the fish would appear to be protecting territory, there is really very little threat from others in the school.

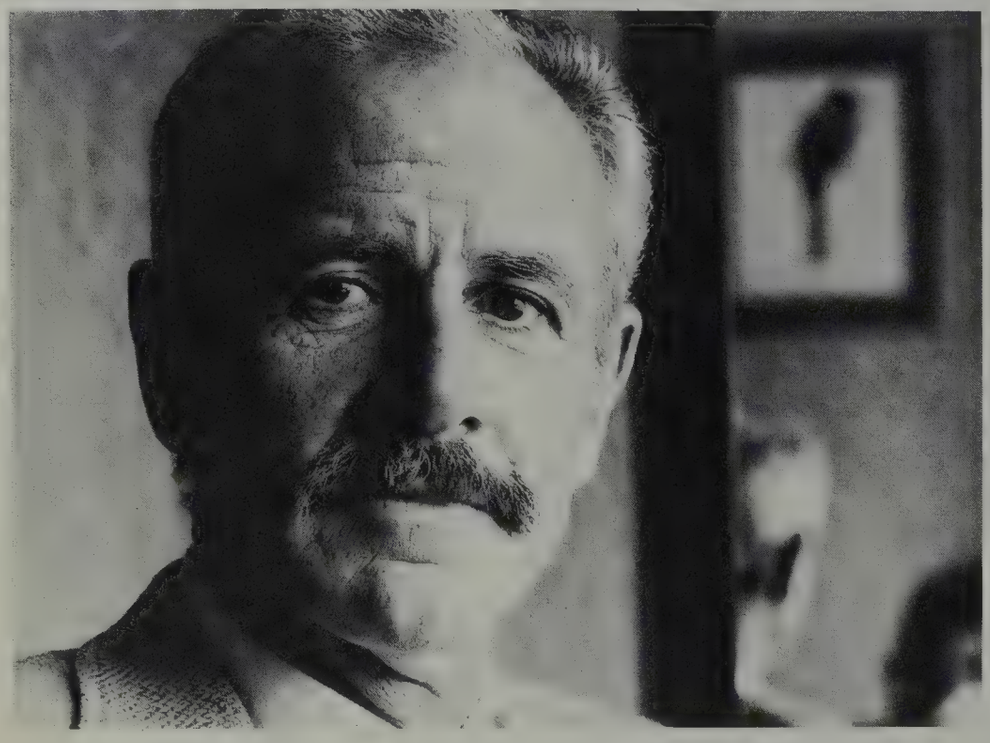
Grunts are abundant on the coral reefs off the coast of Florida and in the Caribbean, and common to warm seas around the world. The name comes from the gutteral sounds the fish makes when the grinding of its pharyngeal teeth, those back near the opening to its throat, resonate off its swim bladder.

Grunts swim during the day in dense schools, then disperse in the evening to feed alone on nearby sand beds. Woodward said the school that this fish seemed to dominate for the several days he observed was made up of twenty-five to thirty fish all within a two- to three-square-yard area of reef. William McFarland and Zandy-Marie Hillis have theorized that the more aggressive fish in the school act to keep the others swimming in a manner that makes the most efficient use of their schooling territory, while giving them the most protection from predators. If, for instance, fish of the same size school together, individuals are much less likely to be picked out for prey than, say, a small fish swimming in a group of larger fish.

This grunt may not have been the school bully, but simply acting as an overzealous monitor. — *B.D.S.*

Photograph by Dave Woodward

Authors



Although Tsaparang was only a side trip on his journey to and from sacred Mount Kailas in Tibet, **Frits Staal** (page 34) saw in this abandoned citadel further evidence of the kinship among Asian religions and cultures. A professor of philosophy and South Asian languages at the University of California, Berkeley, Staal travels extensively, often by motorcycle, throughout India, Nepal, and the Himalayas. He has written about the cultural and religious traditions of these lands and made recordings of mantras and recitations. To reach Tsaparang, Staal and his group, the first Westerners to visit in more than forty years, spent four weeks traveling across China in four-wheel-drive vehicles. Staal says he'd rather make his next trip on foot with pilgrims from India. For further reading, he recommends *Indo-Tibetan Buddhism,* by David Snellgrove (Boston: Shambhala Publications, 1985) and Charles Allen's *A Mountain in Tibet* (New York: Andre Deutsch, 1982). His most recent work is *Agni: The Vedic Ritual of the Fire Altar, 2 volumes* (Berkeley: Asian Humanities Press, 1983).

His scuba-diving instructor number, 29, puts **Dave Woodward** (page 88) among the first certified to teach the subject. Since 1965 he has been diving and photographing in the Caribbean. He shot the French grunts (for this month's "Natural Moment") off San Salvador in the Bahamas, where for the last four years he has served as resident professional in underwater photography at the Riding Rock Inn. The photograph was taken using Ektachrome professional film, ASA 64, in a Nikon F2 fitted with a Nikor 55-mm macrolens and two Ikelite 1501 strobes.

Over the course of the last ten
Andrew T. Lloyd (page 46) has l
for and at cats on four continents, e
a Ph.D. from Boston University, a
corded genetic and biogeographic
formation on more than 15,000
While in the United States, Lloy
native of England—became an en
astic devotee of American diners
der to sustain a grueling schedule p
ing the pavement in search of more
He has since returned to Britain,
he teaches at the University of Ne
tle-upon-Tyne. Without the distra
of diners and bluegrass music, h
spends less time on the streets and
in the laboratory, where he is also
ing the population genetics of fe
geons. For general background o
Lloyd suggests Muriel Beadle's *Th*
(New York: Simon and Schuster
1979). Readers wanting to learn
about the study of cat genetics ca
to Neil B. Todd's article "Cats and
merce" (*Scientific American,* N
ber 1977).

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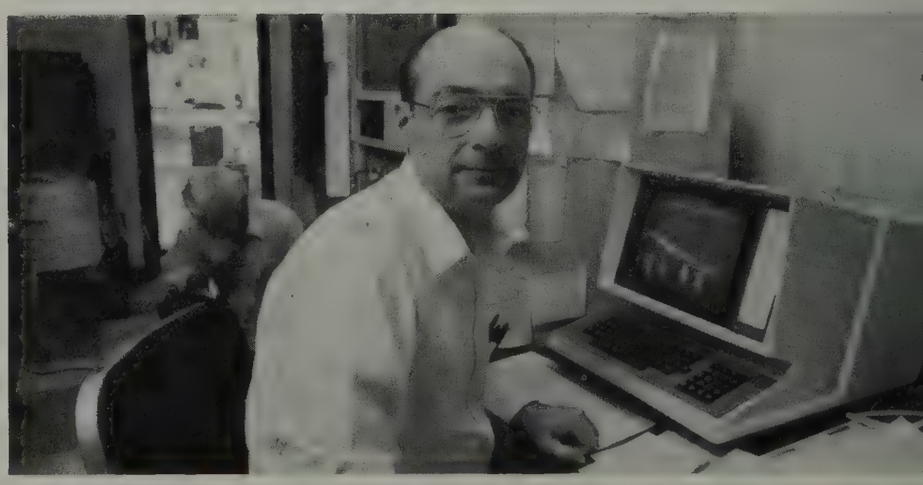
Authors, continued

During a class outing, a sharp-eyed student called the attention of **Luther Brown** (page 54) to the forked fungus beetles inhabiting shelf fungi on dead trees. Although many horned beetles are exotic looking and elusive, Brown and his coauthor **Larry Rockwood** have found the fungus beetle, a homely local species, to be a perfect subject for studying the evolutionary mystery of beetle horns. Both Brown (right) and Rockwood (left) are associate professors of biology at George Mason University in Virginia. Rockwood has studied tropical leaf-cutting ants and is now investigating ant–plant mutualisms, especially seed dispersal by ants. Brown is currently writing a book on behavioral ecology. Among his future projects are studies of the mating systems of guinea fowl and the singing oyster toadfish. Brown spends all of his spare time on his small farm in southwestern Virginia, where animal interactions include those of his "dwindling duck flock" and the "booming fox population." For further reading he recommends "Beetles Adorned with Horns," by Daniel Otte (*Natural History,* August 1980).

As a northeasterner, **Kenneth A. Rahn** (page 62) became interested in acid rain in the early 1980s when its appearance in the Northeast first became a major local issue. He had already investigated Arctic haze and put in time as a research associate at universities and institutes in Norway, West Germany, and Belgium. Rahn (right), who has a Ph.D. in meteorology from the University of Michigan, is a research professor at the Center for Atmospheric Chemistry at the University of Rhode Island's Graduate School of Oceanography. His article in this issue is the second he has written for *Natural History* (see "Who's Polluting the Arctic?" May 1984). Despite acid rain, one of Rahn's hobbies is gardening. Coauthor **Douglas H. Lowenthal** was one of Rahn's graduate students. For five years he has been a marine research specialist, with a specific interest in "using chemical elemental signatures to determine distant regional origins of atmospheric pollutants." Before becoming involved in the field of atmospheric chemistry, Lowenthal was a professional guitar player in local clubs. For readers who want to learn more about acid rain in general, two books may be u
Acid Rain, by Robert H. Boyle a
Alexander Boyle (New York: Sh
Books, Inc., 1983) and *Acid Earth
Global Threat of Acid Pollutio*
John McCormick (Washington,
Earthscan, 1985).



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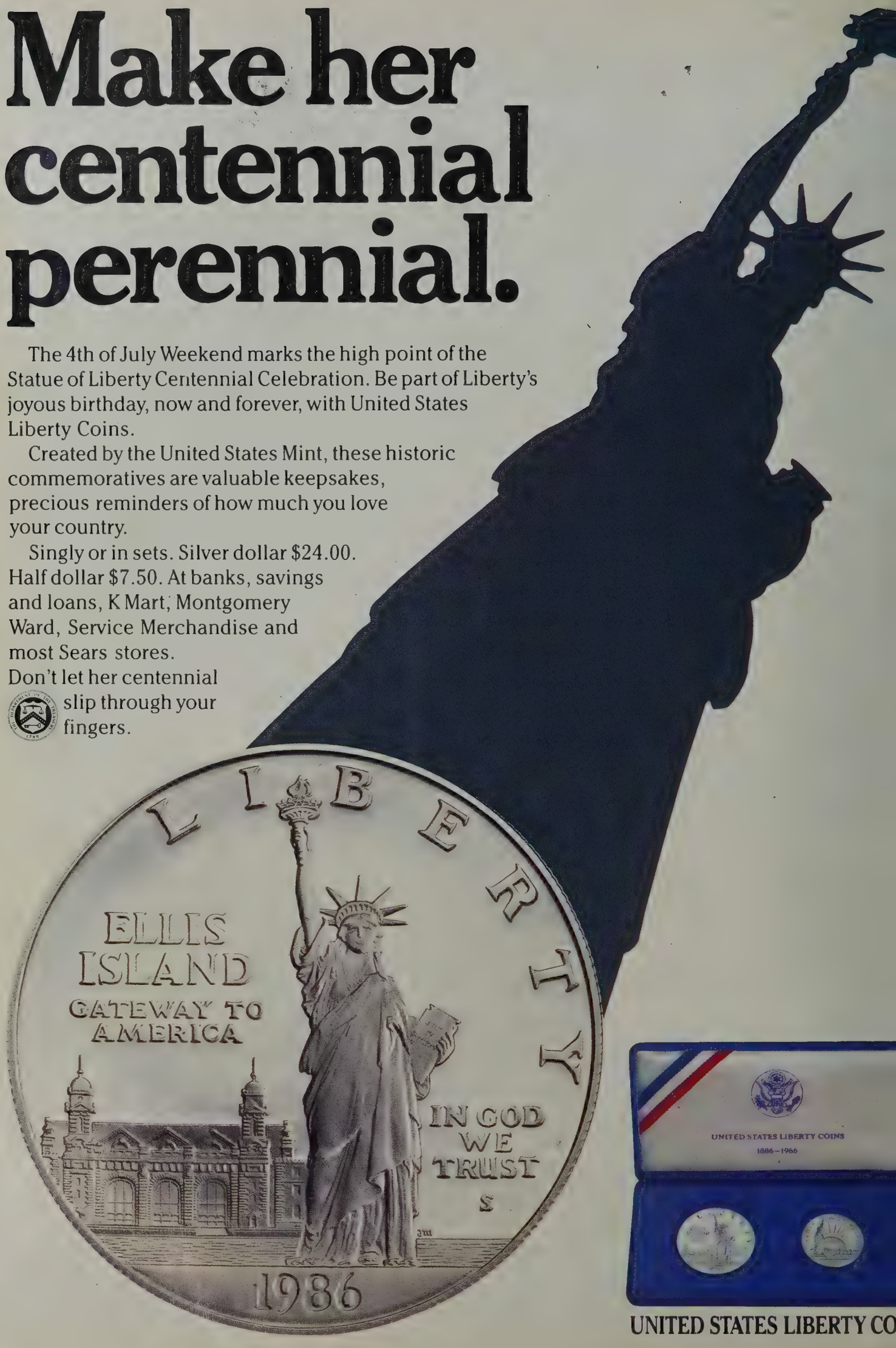

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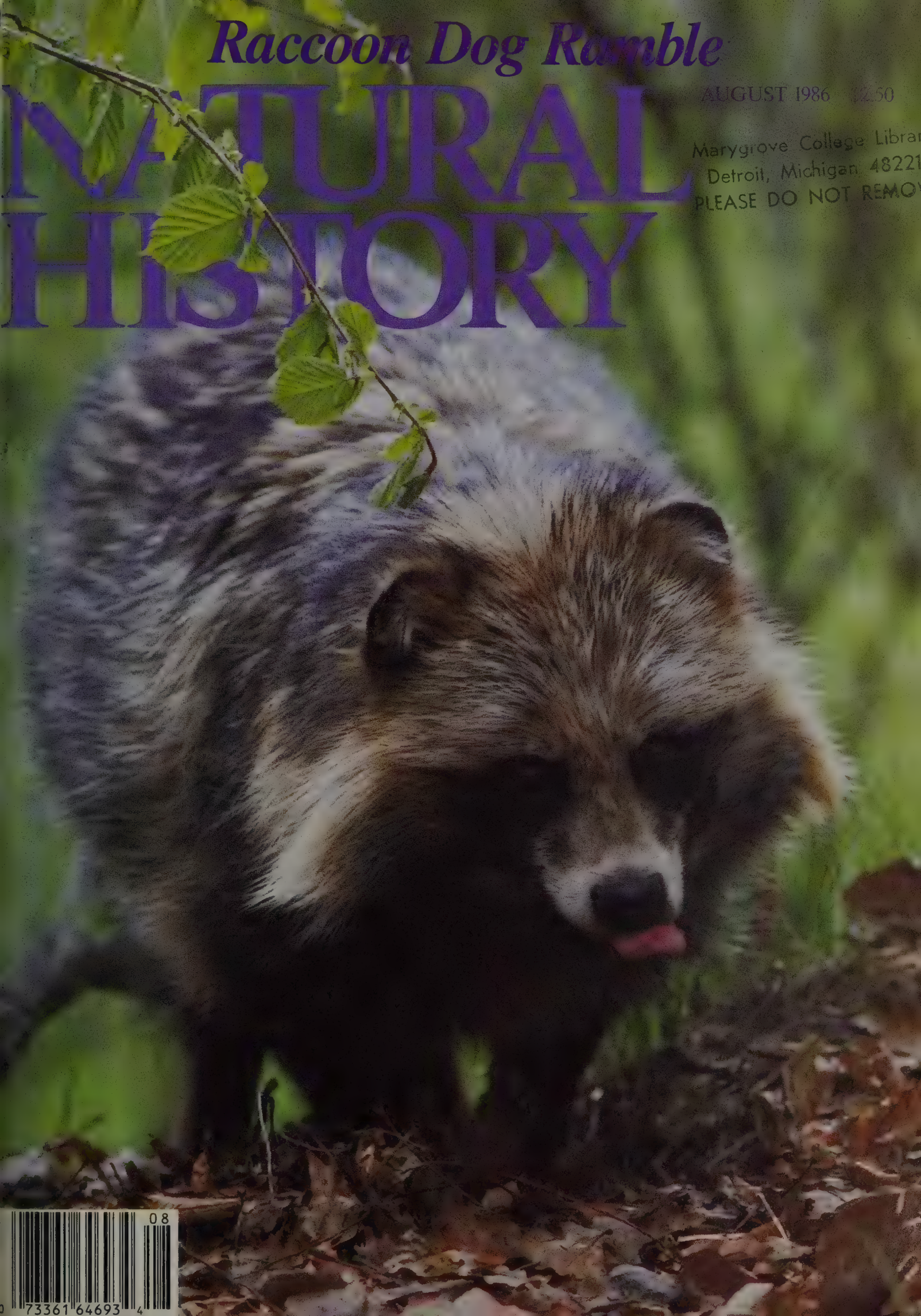

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Vol. 95, No. 8, August 1986

American Museum of Natural History, New York, N.Y.
Robert G. Goelet, President
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2 Letters

4 Blunder in Their Footsteps *Laurie R. Godfrey and John R. Cole*
Many creationists want a tall tale from Texas to be true.

16 This View of Life *Stephen Jay Gould*
Linnaean Limits

24 Reviews *Robert R. Ream*
Following the Pack

30 Is There Life After Strip Mining? *Branley Allan Branson*
Recovery, if it comes at all, is a very slow process.

38 Old Dogs, New Treks *Hiroshi Ikeda*
The tanuki, *an ancient and adaptable Asian canid, has made a home for itself in modern Europe.*

46 Good Vibrations *Charles S. Henry*
Lacewings may look alike, but different species mate to the sounds of different drummers.

54 A Harvest of Decay *E.O. Wilson, photographs by Thomas Eisner*
When leaves die, they produce a symphony of color.

58 This Land *Robert H. Mohlenbrock*
Taylor River, Colorado

62 Sky Reporter *Stephen P. Maran*
Gaps in the Asteroid Belt

66 Celestial Events *Thomas D. Nicholson*
No August Doldrums

72 The Living Museum *Bruce Stutz*
Fish Market Taxonomy

80 A Matter of Taste *Raymond Sokolov*
Hooking a Snook

84 The Natural Moment *Photograph by Tui De Roy*
A Sanguine Approach

86 Authors

Cover: *A raccoon dog on the hunt. Native to the Far East, raccoon dogs are now found throughout western Russia and much of Europe. Story on page 38. Photograph by Hans Reinhard; Bruce Coleman, Inc.*

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Sperm Whales, Gentle and Otherwise

Hal Whitehead claims to have dispelled Melville's image of the sperm whale as vicious ("A Naturalist at Large," June 1986). But this is a case of comparing apples and oranges.

Whitehead is basing his thesis on a study of the sperm whale in a non-adversarial environment, after years of very reduced whaling under International Whaling Commission strictures.

Melville, and other writers of the day, were describing a period when sperm whaling was at its height and largely recording behavior subsequent to harpooning. The sperm whale, very much like its terrestrial counterparts, is shy and will not initiate an attack against humans unless threatened or wounded.

Incidents like that of the *Essex*, in which ships were rammed and sunk by sperm whales, were indeed rare. Only one other case is known—that of the *Ann Alexander* in 1851. But the numbers of whaleboats stove in, broken in two, capsized, or sunk were legion. Virtually every logbook of whaling voyages of the period recounts the very high toll of whaleboats and the need for experienced carpenters aboard for their repair.

As a matter of fact, the seal of the Old Dartmouth Historical Society, which operates the New Bedford Whaling Museum, is a representation of a sperm whale smashing a boat.

IRWIN MARKS
Vice Chairman,
Volunteer Council
New Bedford Whaling Museum
Acushnet, Massachusetts

Idaho Chowder

In reference to "Chowder Chauvinism," by Raymond Sokolov ("A Matter of Taste," May 1986): A "true" clam chowder with Idaho potatoes?

A Maine Chauvinist
U.S. Navy, APO San Francisco

How dare you suggest that Theophrastus has logic on his side in his recipe for New England clam chowder! It is ludicrous to suggest that my ancestors imported Idaho potatoes when they had a whole back field full of them. Other than that point, I'd vouch for the purity of his recipe, though we saw nothing wrong with a little butter, salt, and pepper.

PATRICIA I. FELTON
Limerick, Maine

"Sperm Whale in a Flurry," by Currier and Ives

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Post-mortem of the Post-mortem

In "Post-mortem at the Little Bigh
(June 1986), Douglas D. Scott and
lissa A. Connor inform us that "some
riors scalped the dead or mutilated t
remains, as was their custom in warfa
and "many of the cut marks and crus
skulls may have resulted from mutila
of the dead, a normal cultural expres
of victory for Sioux and Cheyenne
riors." At the battle of the Little Bigh
however, the Cheyenne and Sioux
practicing techniques of mutilation t
had learned from the Europeans. Thirt
years earlier, for example, Cheyenne
Arapaho groups were camped at S
Creek, Colorado, where they were assu
of safety by white officials and had
rendered their arms to the white soldi
These defenseless men, women, and
dren were then massacred by the w
army, which mutilated, castrated,
headed, and scalped them. It is the Na
Americans who are continually portra
as "barbaric" and "savage," yet hist
tells us that it was the white newcom
who introduced and practiced these
tesque customs.

REBECCA JO
Madison, Wisco

The interesting post-mortem and li
graphs of Custer's battle made me won
about the following: Where were Cust
200 or more horses and their guar
Were they killed? Were the horses sh
and if so, where were the shoes? You
that no U.S. soldiers are shown on hor
but a few Indians are. It seems to m
have read of horses being killed and u
as breastworks in a fight—no mentio
your account. It also seems to me t
about every fourth or fifth cavalryn
was a horse holder when cavalry fou
dismounted.

EVERETT OER
Baton Rouge, Louisi

Douglas Scott and Melissa Connor re

There is good archeological evide
that prehistoric American Indians pr
ticed scalping and mutilation before

ırrival of the Europeans. It was certainly ɔresent in the Plains area during prehis-oric times.

During the era of the Battle of the Little Bighorn, marking a vanquished foe hrough scalping, slashing the body or ex-remities, or cutting off body parts was a ɔart of the cultural heritage of the North-ɛrn Plains groups. It was a means to insure hat the foe could not enjoy the full fruits ɔf the spirit world in the afterlife.

In our own cultural context, mutilation nas a negative connotation. This was not he case for those American Indian groups who practiced it on their enemies. Mutila-ions inflicted by our troops on the Indians at Sand Creek or in other fights were barbaric in our own cultural terms, but we cannot view Indian mutilation of enemy dead in the same perspective.

As for the fate of the horses at the Little Bighorn, there were indeed more than two hundred horses with the Custer command. Historical accounts suggest about ninety horses were found dead on the battlefield, including some Indian ponies. The other army horses were most likely captured by the Indians or wandered away. All of the army horses were shod, and a number of horseshoes were recovered during the archeological project. Horse bones were also found, although most of the horse bones had been gathered up and buried in a mass grave during the 1880s in an effort to give the battlefield a neat and clean appearance.

It is true that every fifth cavalryman was assigned as a horse holder when dismounted for fighting. Indian accounts of the battle suggest that regulations were followed during the battle, but the intense gunfire frightened the horses and most bolted. A number of horses were found dead on Last Stand Hill, where Custer's body was found. This led to the speculation that some horses were killed to form a barricade, although opinion on this was divided among those who actually helped bury the dead. Because of the cleanup of horse bones in the 1880s, little archeological evidence was recovered that bears on this matter. □

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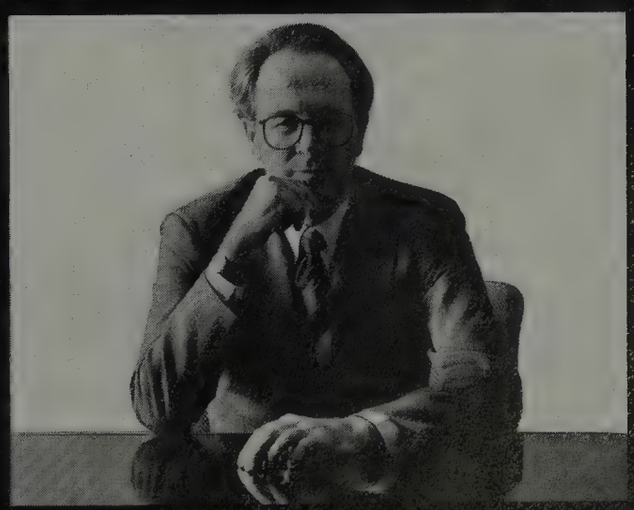

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Blunder in Their Footsteps

Creationists still cite the Texas "mantracks" as evidence that dinosaurs and humans coexisted

by Laurie R. Godfrey and John R. Cole

Fossil hunter Roland T. Bird was on the verge of leaving the Southwest empty-handed. In light of his previous record of fossil finds, the 1938 field season had been unproductive and particularly disappointing. Working for Barnum Brown, a paleontologist at the American Museum of Natural History in New York, Bird had been involved in some of the most successful fossil hunting in the Museum's history. Just a few years earlier, Brown had discovered great caches of Jurassic dinosaur bones, concentrated like logs in a giant log jam, at the foot of Wyoming's Bighorn Mountains, and Bird had helped excavate these fossils. Now, as Bird was about to pack up and head from New Mexico to New York, a local drayman assisting him mentioned a shop that offered some unusual fossil footprints for sale. Weary but determined, Bird made his way to Jac Hill's curio shop in Gallup, where tw huge humanlike footprints were exhibite in the window.

The footprints were obvious phonies– Bird's first reaction was "who's been car ing those things out of stone to fool pe ple?"—and he had little inclination to pu sue their origin. But when the store cler told him of more footprints—real din

This photo of carved "mantracks" appeared in Roland T. Bird's 1939 Natural History *article.*

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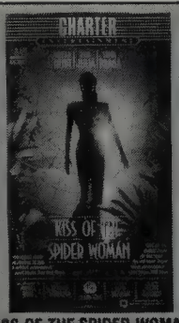

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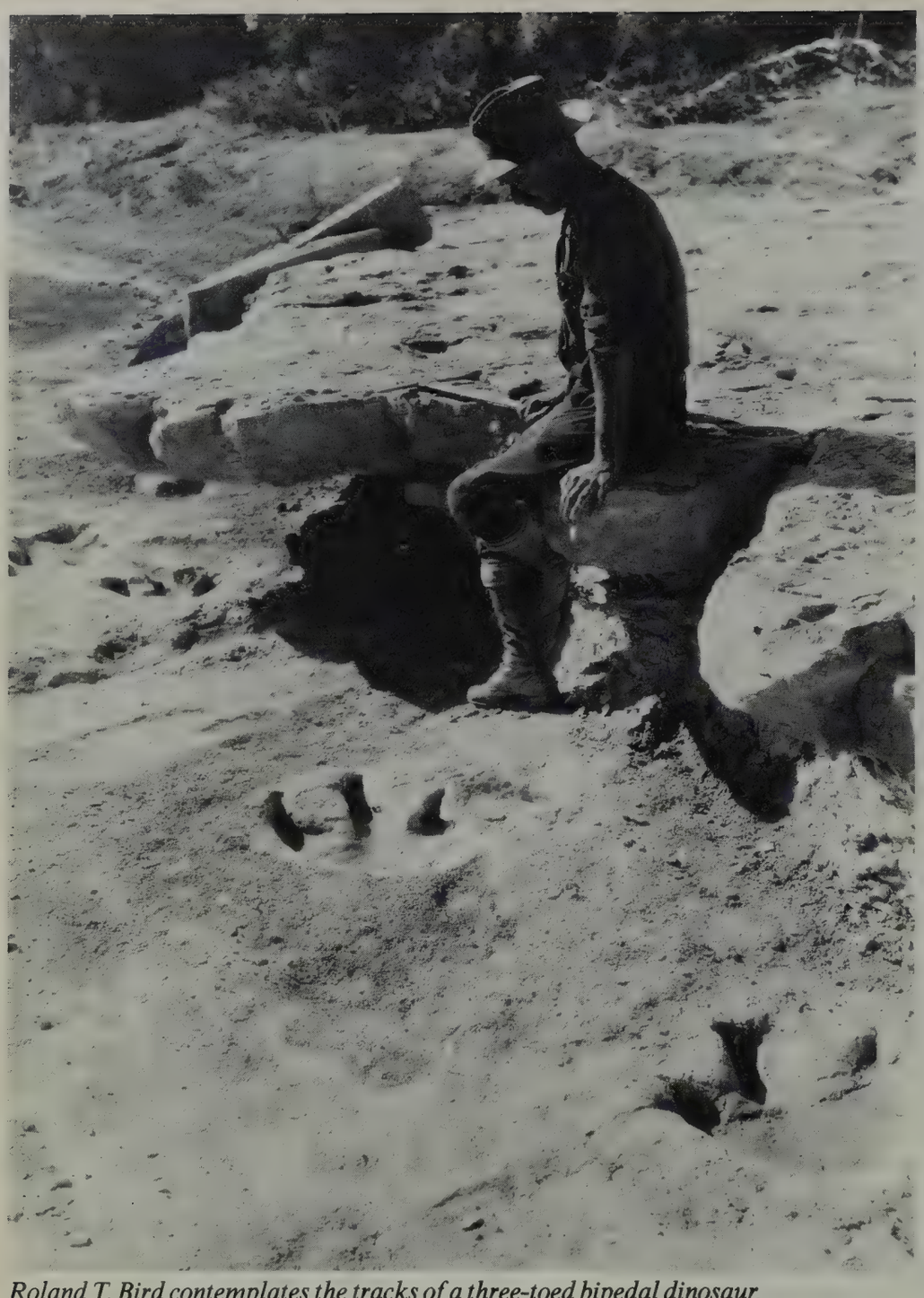

Roland T. Bird contemplates the tracks of a three-toed bipedal dinosaur.

saur prints—for sale in another of Hill's shops, Bird's curiosity was piqued. On arriving at the shop in Lupton, Arizona, Bird saw that the dinosaur prints, too, were carved, and his expert assessment was immediate: "The claws of the prints were too perfect. When a beast pulls a claw out of mud, he doesn't leave a perfect copy; the mud slurps about a bit." Still, the tracks displayed accurate, if overly precise, anatomical details. While Bird could imagine a craftsman producing a likeness of a human foot, he could hardly believe that someone could replicate dinosaur prints without a genuine model. Bird resolved to drive to Glen Rose, Texas, near Paluxy Creek, where Jack Hill had purchased the tracks a few weeks earlier.

The lead turned out to be a lucky one for Bird, Barnum Brown, and the Museum. Jack Hill's anonymous carver had inadvertently led Bird (and in subsequent years, thousands of Museum visitors) to the extraordinary dinosaur trackways now on exhibit in the Dinosaur Hall of the American Museum. During the Depression, some Glen Rose residents had indeed fabricated humanlike and dinosaurlike footprints to sell to tourists. But there were also real dinosaur footprints in the 100-million-year-old rocks of Glen Rose. The area was a gold mine of trackways of two-legged carnivores and of four-legged herbivores, some related to *Apatosaurus,* better known as *Brontosaurus.*

Bird's recounting of this serendipitous event appeared in *Natural History* magazine in 1939, along with a photograph of the carved human footprints that had spurred his quest for dinosaur tracks. But this boon for paleontology and the study the evolution of life soon took a bizar turn. Bird's account caught the attenti of creationist Clifford Burdick, who 1945 set out to find the "human" track which he believed to be genuine. He pers vered until he located them in a sm museum in Arizona. The coexistence dinosaur and human tracks would vin cate the belief that all living organisr were created virtually simultaneous from nothing, and that all living thing and even the earth itself, had come in being just a few thousand years ago. T dinosaurs and other long-vanished ar mals were, according to some literal inte pretations of the Bible's account, annil lated by the Flood. Burdick had been young man during the Scopes era, wh the scientific establishment had humi ated William Jennings Bryan for deridi those who would study the "age of rock rather than the "Rock of Ages." No with these new finds, Burdick seized t opportunity to put science in the service the creationist credo.

Burdick believed the enormous carv tracks provided proof of degenerati from a golden age: "Not only has ma decreased in stature from a magnifice specimen ten or twelve feet tall, to a average today of less than six feet, but h average life has shortened from many ce turies to little more than half a centur Where do we find any human evoluti here?"

Soon the purported existence of huma footprints alongside dinosaur trails b came a rallying point in antievolutioni circles. Books hailing a new era of scie tific creationism featured them as cruci evidence refuting the geological timetab and evolution itself. Teams of creationis made the pilgrimage to Glen Rose hopi to discover more evidence against evol tionary theory. Some of the most arde believers in Burdick's original huma tracks eventually concluded that th were carved, and twenty-five years aft Burdick had published his news, the Se enth Day Adventist publication *Origi* carried a story renouncing the carv tracks. But from the late 1960s until qui recently, books, films, and news releas have described spectacular new discove ies of "genuine mantracks" in the Cret ceous rocks of the Glen Rose area. Suc discoveries continue to be touted despi occasional retractions and critiques of pa ticular examples coming from some of th creationists themselves.

Some of the most sensational rece claims have been made by the Reverer Carl Baugh, the latest of the Palu creationist track hunters. When added

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earlier claims noted here and elsewhere, the list is truly impressive and now includes alleged discoveries of a "monkey or human child skull," a human handprint, saber-toothed tiger prints, a bear track, chariot tracks, and an ancient hammer, all supposedly contemporaneous with the dinosaur tracks. Baugh claims to have found at least forty-four human tracks amid dinosaur tracks on Emmett McFall's property near Glen Rose. The prints deemed to be human range in length from nine and three-quarter inches (seven tracks "made by a woman" Baugh calls Beverly) to twenty-two inches (five tracks "made by a thirteen-foot-tall, 600-pound man").

With geologist Steven Schafersman and physicist Ronnie Hastings, we visited the track sites in north-central and south-central Texas to find out what this array of features really was. Our efforts join those of others, including Glen Kuban and vertebrate paleontologists James Farlow an Wann Langston, Jr. We found that nor of the features are what the creationis allege. Some are carved fakes. Some a genuine tracks made by bipedal dinosau or scour and solution erosional feature Others are exposed and partly eroded bu row casts of invertebrate organisms.

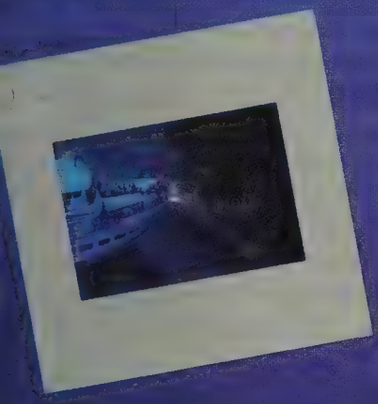
The carved fakes were the most easi diagnosed. A giant track now on exhibit i front of the Gibbs Sanitarium in dow

TEXAS "MANTRACK" SITES AND CLAIMS AT A GLANCE

Creationist Claims	What These Features Actually Are
Features in or collected from Glen Rose area (Dallas-Fort Worth region)	
Dinosaur Valley State Park ledge: mantracks in right–left series; bear track; brontosaur track; track on cover of Cecil Dougherty's Valley of the Giants	*River erosion produced elongated features in apparent right–left sequence; scour erosion with undercutting produced the "pads" and "claws" of the bear and brontosaur tracks. Solution erosion along fissures produced oblong mantracks. Erosional feature displayed on Dougherty's book has been identified as both a right and left footprint by creationists.*
Gibbs track on display in Glen Rose	*Humanlike footprint carved in cement; many anatomical errors.*
Caldwell track. Aluminum casts are being sold by Carl Baugh for $100 each	*Humanlike footprint known by local people to have been carved in the 1930s.*
Mantracks originally in private collection of Clifford Burdick	*Carved fakes (and casts from them) dating to the 1930s. Two were discovered by Roland T. Bird in a Gallup, New Mexico, curio shop. Recently purchased on behalf of Columbia Union College in Maryland. None show the characteristics of a human footprint made in soft mud.*
Von Däniken mantrack (also called "Dougherty track" by John Morris in Tracking Those Incredible Dinosaurs and the People Who Knew Them)	*Portion of a three-toed dinosaur footprint near Cherry and Dougherty trails, painted with water or oil to conform to the outline of a human footprint and then photographed.*
Mantracks on E. McFall's property near the town of Glen Rose, central Texas. Recently publicized by Carl Baugh. Human handprint. Saber-toothed tiger footprints	*Tracks include three-toed dinosaur "heel" impressions, drag or slip marks, other elongated heel marks produced by contact of the rear of foot with the surface, and collapsed dinosaur tracks, with features obscured by wet mud collapsing back into track upon original formation. So-called saber-toothed tiger tracks, one alleged manprint, and probably the handprint (original removed before we arrived; photograph only was examined) are rock surface features and burrow casts or crawl marks made by a Cretaceous crustacean. They form irregular patterns that creationists have identified as toe, finger, and palm prints.*
Human trails in the region of Glen Rose: Taylor Trail, Ryals Trail, Turnage Trail, Giant Run	*Trails produced by bipedal three-toed dinosaurs. Most represent dinosaur heel marks—apparently produced by the rear of the foot contacting the ground. Toe marks visible in some only by discoloration produced by oxidation of iron particles in the rock upon exposure and weathering. Others appear to be collapsed footprints. All trails show stride length and step angle patterns typical of bipedal dinosaurs, as well as some evidence of three toes.*
South-central Texas, San Antonio area	
Mantracks on Ken Thayer's Dinosaur Flats, near New Braunfels, Texas	*Some are overtracks of three-toed dinosaur footprints (formed when layers of sediment filled primary footprint molds, obscuring their original shape); some are solution features.*
Chariot tracks near Canyon Lake, Texas	*Chariot tracks on Ken Thayer's property appear to have been produced by a moving inanimate object, such as a water-tossed log.*
Other claims	
Mammoth fossils, "monkey or human child skull," exhibited at creationist conferences	*Limestone concretions, weathered rocks of miscellaneous shapes; teeth on so-called skull are silica spurs.*
"Ordovician" iron hammer (from London, in west-central Texas)	*Nineteenth-century miner's hammer enveloped in a concretion—a secondary formation that can develop in a decade.*

Based on research conclusions of L. Godfrey, J. Cole, S. Schafersman, R. Hastings, G. Kuban, and others, originally reported in Creation/Evolution.

We walked beaches as secluded as Robinson Crusoe's. And we found few footprints.



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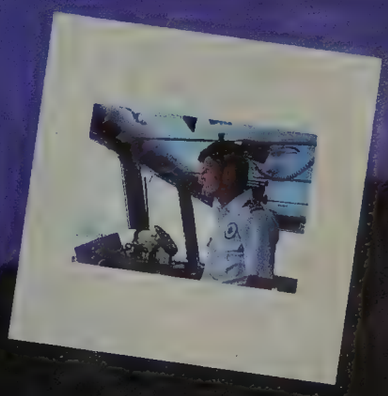

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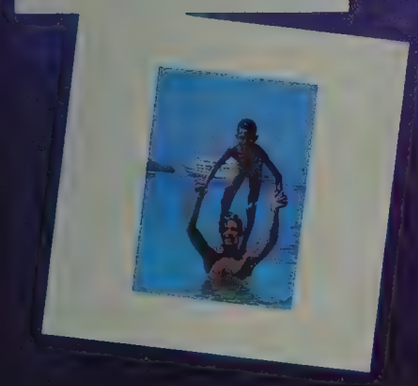

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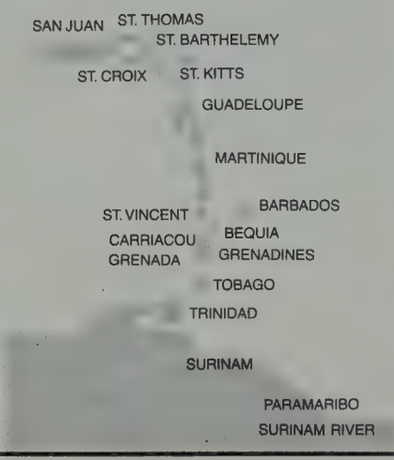

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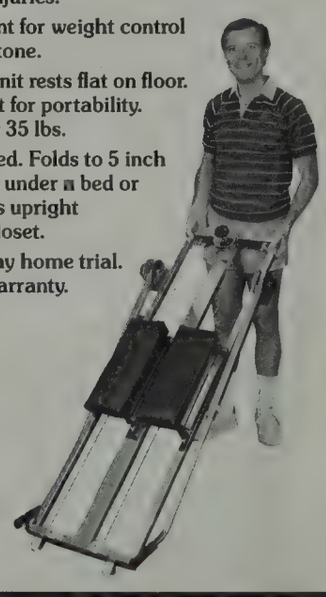

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town Glen Rose is made of cement an supposedly reconstructs a genuine trac underlying the current surface. (Accord ing to property owner Grover Gibbs, ce ment was poured into the track to repair i after it was vandalized by youths.) Bu like the Burdick tracks, it exhibits a suit of anatomical errors that can be detecte by anyone with even a rudimentary know edge of tracks.

The features of human footprints de pend, first, on the surface on which the are impressed. On hard surfaces such as fairly dry lime mud, human footprints ar extremely shallow and assume hourglas shapes (just as they do when a person wit wet feet walks across a hard floor). Th entire sole does not print because th raised arch in the middle of the foot doe not touch the surface. Light imprint made on hard surfaces reflect the contac of the different parts of the sole during th normal walking cycle: pressure shifts fron the heel to the outer edge of the foot an then inward across the ball of the foot t the big toe, which bears the brunt of bod weight during push-off. On a hard su face, one can expect to see little more tha the outline of the heel, the outside of th foot, and impressions of the ball of the foo and big toe. The little toes typically leav only slight impressions on hard surfaces

On wet sand or mud, human footprint do not assume hourglass shapes becaus the entire undersurface of the foot sink into the ground. In this case, the footprin clearly shows anatomical details of th entire sole and features of the rolling hu man stride. Footprint depth is grea throughout but greatest at the heel an ball and most shallow at the arch. Mu oozes into the curl of the little toes, creat ing a slightly raised ridge separating th imprints of the pads from the ball. Thi ridge disappears at the great toe, whic makes a deep depression continuous wit that of the ball of the foot. The carve tracks, despite their great depth, exhibi none of the features characteristic of hu man footprints made in soft mud.

Human trackways have characteristi relationships between foot length, stride and pace lengths. If the prints are too clos together or too far apart for the foo length, or if they are unevenly spaced they cannot be of human origin. Eve when the features of a print have bee obscured by mud or are faint because the were made on a relatively dry surface, th overall pattern allows the track specialis to distinguish among trails made by ver different animals.

Usually, one need not even take int account step angles or pace and strid lengths to distinguish dinosaur from hu

nan tracks. Bipedal dinosaurs tracks are enerally unmistakable: the tracks of hree-toed, or tridactyl, dinosaurs usually ook very much like giant turkey tracks, vith three distinct toe impressions. Despite that fact, trails made by bipedal dinosaurs, showing the regular right–left atterns of all bipedal animal trails, are nore easily confounded with human trails han are complex trackways made by quadrupeds. Individual dinosaur toe impressions can vaguely resemble human ootprints (although they tend to be arger), and tridactyl dinosaur "heel" impressions can look superficially human, because some three-toed dinosaurs made elongated heel depressions. These may have been produced by a cushion behind he toes or by the rear part of the foot tself. And some three-toed dinosaurs, like nodern birds, actually possessed a fourth oe, or hallux, on the rear of the shank, hat may have occasionally contacted the urface when the dinosaur's foot sank sufficiently deeply into it, leaving a pointed nark at the rear of the footprint. Finally, ome "heel marks" may actually be slide or drag marks and not specific anatomical eatures of the foot of the dinosaur.

Other dinosaur footprints may suggest human tracks because they were partly washed out by water or filled in by collapsing mud prior to fossilization. Still others may vaguely resemble human footprints because, for other reasons, they preserve none of the details of the structure of the dinosaur foot: for example, some tracks are actually only secondary molds in layers above and below the original dinosaur footprint molds. To distinguish these from human tracks, characteristics of the entire trackway may have to be taken into account.

The best known of the Glen Rose "human trackways" (including the Ryals and Taylor trails publicized in such books as John Morris's *Tracking Those Incredible Dinosaurs and the People Who Knew Them*) have recently been mapped by Ronnie Hastings and Glen Kuban. The long strides and pace lengths, as well as the variable step angles, show them to be the trails of three-toed dinosaurs. Some individual tracks in these trails lack toe impressions; others show faint toe and claw impressions. They also show deeply impressed, elongated heel marks that Glen Kuban has suggested were produced

A genuine dinosaur trackway flanking Paluxy Creek reveals 100-million-year-old footprints of a two-legged carnivore and its four-legged prey.

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by a dinosaur dropping the rear of its foot onto the ground. Weathering of the Taylor and other trails has made the three clawed-toe marks in front of each depressed heel mark quite visible despite their lack of depth. These celebrated trackways were clearly not produced by giant humans.

Anyone uncritically examining rocks for oblong features roughly the shape (if not the size) of human footprints can usually find them. Some alleged human tracks were neither carved nor produced by bipedal dinosaurs. A surprising number, including some in series, are scour erosional features. Erosion of limestone by rivers or floodwaters can create intricate surfaces. Even when these features occur in series, the pocks differ in shape and size and are separated by uneven distances. Limestone is also subject to solution erosion, or leaching, which occurs when rainwater seeps into fissures and enlarges them. Elongated cavities produced in this way can remotely resemble human footprints; small oval pits may be taken as toe marks. Some of the publicized human tracks at Ken Thayer's Dinosaur Flats, near Canyon Lake in south-central Texas, are solution features. All of the well-publicized "mantracks in series" on a hard limestone ledge at Dinosaur Valley State Park are also purely erosional features—both scour and solution. Nearby lower rock strata at Dinosaur Valley State Park contain true dinosaur tracks.

Sedimentary rocks hold many traces, aside from footprints, of the lifeways of ancient organisms, including invertebrates, leaving their marks as fossil traces. Perhaps the most remarkable of so-called human and other tracks (including those of a saber-toothed tiger), which Baugh and his crew imagine they saw, are made up of invertebrate burrow casts called *Thalassinoides*. These were made by a crustacean whose burrow systems are common in Glen Rose limestone. At the Thayer site, creationists have identified long parallel features as chariot tracks. They seem to have been produced by an inanimate moving object, such as a water-tossed log.

Touted as a human artifact of a time when humans and dinosaurs coexisted, the iron hammer found near London, in west-central Texas, fifty years ago, and recently acquired by Baugh, is a nineteenth-century mining tool. It was found embedded in a rock concretion that Baugh asserts is Ordovician, an epoch that geologists date from about 400 million years ago. The source rock may well be Ordovician, but the concretion itself is nineteenth century. Concretions form when water containing dissolved minerals evaporates and the minerals are deposited on objects that then become enclosures in rock. Pieces of modern glass have been found in limestone concretions in Bermuda, and World War II artifacts in the Pacific have been found encased in stone. The hammer, dated stylistically, is a nineteenth-century relic probably dropped by a miner into a crack in the Ordovician rock and subsequently washed over with sedimentary slush that then hardened. Baugh reports correctly that the metal of the hammer head was made by a modern process, but he is wrong to conclude that modern metallurgy thus predates the Deluge. He ran a carbon 14 dating test on a piece of wood from Michigan that he said resembled the handle of the Ordovician hammer and obtained an age of 11,500 years. He has not tried to date the hammer in question.

Roland T. Bird, who brought national fame to the Glen Rose area in the 1930s with his spectacular discoveries of dinosaur trackways, was dismayed by the growing interest in the supposed human tracks, an interest that threatened to eclipse the important fossils he had unearthed and his efforts to establish Dinosaur Valley State Park. He regretted having revealed the story of the carved tracks in his 1939 *Natural History* article, "Thunder in His Footsteps." (He had described not only the obvious frauds but also an elongated collapsed dinosaur track that he thought might have stimulated the local human track lore.) Creationists even maintain that Bird knew the mantracks were genuine. One of Europe's leading antievolutionists, A. E. Wilder-Smith, put it this way:

> It is quite interesting to see what is done in scientific circles with such awkward observations as contemporaneous dinosaur and mantracks. First of all both kinds of tracks were duly reported [in *Natural History*], but it was suggested by Dr. Bird, who first found them, that either the man tracks or the dinosaur tracks must have been falsified, because according to theory, the two could not exist together! . . . The giant human tracks have perfectly clear toe, heel, and arch imprints. . . . Pure theoretical prejudice prevented Dr. Bird from recognizing some exceedingly important geological evidence [against evolution].

"But," Bird explained in a letter to paleontologist Wann Langston, Jr., dated October 29, 1976,

> those were the days when both Barnum Brown and I were dependent on the Sinclair Oil Refining Company for field work grants. As the company sometimes featured Barnum's planned expeditions in their national advertising, it behooved [us] to write articles that would please old Har Sinclair and soften him up for yet anoth season . . . . "Thunder in His Footsteps," i tended for Sinclair's eyes as much as an body's, went to press, with me trying to ad a touch of mystery by bringing in th "mantracks." Who could dream of wh might happen, what *did* happen!

Dinosaur Valley State Park was final opened in 1969, but until his death 1978, Bird was working to establish small dinosaur museum at the park e trance, a project that failed for lack of th few thousand dollars needed. By contra Carl Baugh achieved his interim goal of preliminary creation museum within year and purchased ten acres of land for permanent excavation. He is still, despi a barrage of criticism resulting from scie tific investigation of footprint claims, an despite renewed local efforts to establish Dinosaur Valley State Park museum, pu suing the rest of the $3.5 million he es mates he needs to complete his museum which is designed to be "the size an shape of Noah's ark."

In the past twenty years, the creationi cause has gained momentum. Whi creationists have undertaken little actu fieldwork and can summon little hard ev dence for their general case, the Palu Creek tracks are an exception. As seem ingly concrete evidence of the coexisten of men and dinosaurs, the tracks ha been put to full use in the creationist battle against the theory and teaching evolution. The so-called mantracks ha been served up as empirical evidence f not only a religious but also a scientif model that creationists are determined promote in the public schools. Texas tex book critics Mel and Norma Gabler ha cited the tracks in their fight against th use of biology books that deal with th topic of evolution.

Thanks to vigorous creationist publicit the Glen Rose area has become a mec for fundamentalist pilgrims. "Mantrack continue to be discovered along the Palu because some people would like to belie they are there. In a world where no fa can contravene a literal interpretation the Bible and there is no distinction b tween the Rock of Ages and the age rocks, dinosaur trackways cannot effe tively compete with "Cretaceous ma tracks" and an "iron hammer in stone."

Laurie Godfrey, a physical anthropol gist at the University of Massachusetts Amherst, writes about primates, evol tionary theory, and the creation contr versy. Anthropologist John R. Cole, freelance science writer, is associate ed tor of Creation/Evolution.

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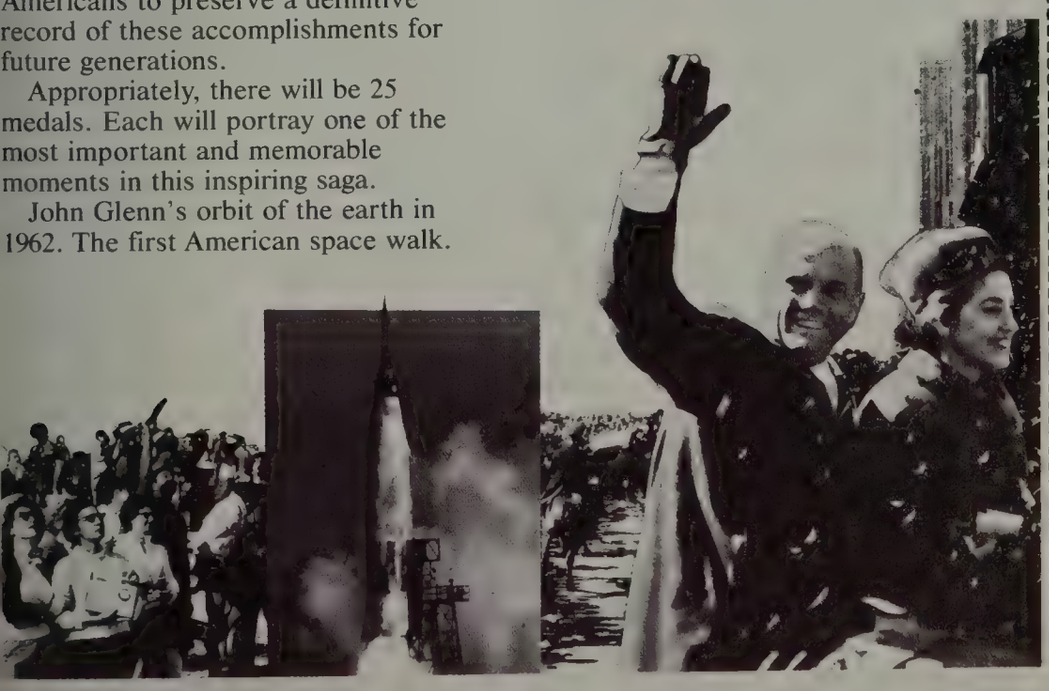

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Linnaean Limits

In some kingdoms, the geometric game of life may be played by different rules

by Stephen Jay Gould

Dressed in feminine garb, Prince Hilarion and his friends sneak into the women's university of Castle Adamant, hoping that their underlying charms might turn the wayward ladies toward proper paths of domesticity. "A women's college, maddest folly going," they exclaim, as they rank the school among all the traditionally impossible projects of Western life. (Their opening line, "They intend to send a wire to the moon," stands as an interesting comment on technological change since Gilbert and Sullivan wrote *Princess Ida* in 1884.) After discoursing on silk purses from sows' ears, sunbeams from cucumbers, the Northwest passage, and perpetual motion, Cyril continues the scoffing:

> As for fashion they forswear it,
> so they say
> And the circle—they will square it
> some fine day;
> Then the little pigs they're teaching
> for to fly;
> And they'll practice what they're preaching
> by and by.

(I can't resist one more tangential comment, this time on social rather than technological change. I have cited Cyril's lines in the modern alteration now used in most performances. Gilbert's original, fourth-line rhyme for "pigs" and "teaching" read—"And the niggers they'll be bleaching, by and by." For all his pointed satire on Victorian stuffiness and pretension, Gilbert was a child of his time [wealthy, white, and male] on matters of race and sex—as he incorporated, *en passant*, this racist dart into his labored spoof of higher education for women.)

Today, we wear on our wrists and use in our kitchens many prime impossibilities of yesterday. In comparison, logic and mathematics may express an inexorability that transcends time and culture. Gilbert was wrong about space travel and Arctic exploration (not to mention higher degrees for women), but no one will ever square a circle (or trisect an angle) by compass and straightedge construction. (For those pitiable few who have forgotten, as I had before I checked, given a line segment that is the radius of a circle, you cannot construct a line segment that will be the side of a square, such that the area of the square equals the area of the circle.) Culture feeds on the realization of its hopes; geometric constraints may be invincible.

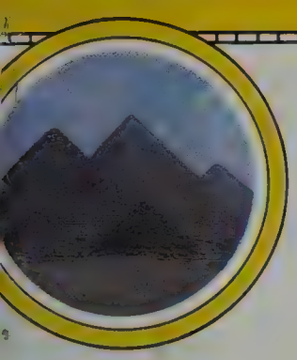
Evolutionary pathways obey a clear and uncompromising geometric regularity. This geometry of change expresses the most fundamental property of life's history; a familiar and accurate metaphor—the tree of life—captures the shape of evolution.

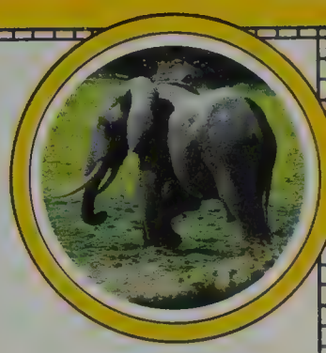
Evolution is a process of continuous branching and diversification from common trunks. This pattern of irreversible separation gives life's history its basic directionality. The geometry of life permits no going back and no amalgamation after separation as a distinct lineage. Once a species arises—and we define species as natural populations of organisms that breed with each other but not with members of other populations—it is on its own forever. Two species may establish tight ties of ecological interaction (as in symbiosis), but they cannot amalgamate in a genealogical sense. Ecoactivists are not purveying political jargon when they exclaim that "extinction is forever." Each species becomes a separate twig on life's bush. It may give birth to other species and generate a new and vigorous limb, or it may die, bringing to a close one small segment of genealogical history that extends back at least 3.5 billion years to the origin of lif on earth. But the twig will not be pre served by casting its lot with other twig and coalescing to form a trunk. Life' geometry of continual divergence pre cludes this pathway to permanence.

The Linnaean hierarchy, our schem for classifying organisms, can only wor under this assumption of continual diver gence. If a new species of rodent, for ex ample, were amalgamated from 20 per cent squirrel, 30 percent prairie dog, 2 percent capybara (for size), 25 percen beaver (for industriousness), and 5 per cent rat (for that edge of nastiness), trad tional taxonomy would fall apart—for w would generate a species belonging to sev eral families. We could not place such species into our classification any mor than we could allocate to one family creation by Dr. Frankenstein cobbled to gether from fifty human sources.

This central geometry of life's histor also explains, more concisely and justl than any other argument, why biologica and social evolution are so different—an why, therefore, our genetic evolutio bears so little meaningful analogy to th development of our civilizations. Cultura history thrives on the very connection that biological evolution forbids. One loo at a cart, and an Aztec might discer another fruitful use for the general shap of circular calendar stones. One moth an one noodle, and Marco Polo changes th technology of Europe forever. Cultura evolution is an intricate web of fertil amalgamation; biological evolution is motor for the generation of independen lineages.

As an exciting field, full of new discov eries and conceptual explorations, evolu tionary theory pursues many vigorous de bates. Some remain mired in the jargon o





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professional literature; others spill over into popular consciousness. Since the vigor of personal advocacy need not map conceptual importance—scholars, after all, are like all of us in their propensity for elevating small personal passions to cosmic relevance—tone and emotional investment are not keys to significance. How then shall we assess the relative importance of these several debates? I would suggest that they be ranked by their impact upon the central ideas of our profession. For example, catastrophic theories of mass extinction rate high on the scale of significance, not because big bangs grab our fancy, but because the rapid and potentially random death that they impose challenges a core belief of Darwinian theory—that natural selection regulates both origin and elimination through a pervasive competition among organisms for reproductive success.

By this criterion, a challenge to the principle of continual diversification would cut even deeper, since the discovery of a mechanism for amalgamation of lineages would question something more general than Darwinian theory—the geometry of evolution itself.

The outlines for such a challenge have been emerging in recent years, although I believe that the potential significance of these new ideas has not been adequately appreciated because they have not been placed in the proper context of a debate about life's geometry. The focus of this challenge has received a proper geometric designation: the phenomenon is called lateral, or horizontal, transfer—the passage of genes from one species to another. No one is suggesting wholesale amalgamation, and we need no more than common sense to realize that our world is not populated by the hybrid offspring of cucumbers and rhinoceroses. But even the ready passage of a few genes from one species to a distant nonrelative would so violate our usual notion of life's order that lateral transfer, if a reality, would greatly enlarge our view of life.

The debate about lateral transfer does not center upon plausible mechanisms. Our exploding knowledge of biochemical genetics provides an evident pathway. Genes may move from one species to another by linkage to a virus that invades a host cell and incorporates itself and its cargo into the host's DNA. The issue is not plausibility but relative frequency. Lateral transfer is intelligible and feasible, but how often does it happen in nature? This crucial question must be established by example, not by theory. (I have often emphasized in these columns that natural history is such a hard science because most of its key questions are debates about relative frequency, not matters of logic or mechanism. In our immense and multifarious world, issues of relative frequency are particularly difficult to resolve.)

Lateral transfer is not a controversial notion for movement of genes among different kinds of bacteria, for we have both mechanisms and examples. Doubt and debate increase when we shift to complex multicellular creatures with intricate embryological development. We may envision transfer of simple and common functions from one bacterium to another, but have we any reason to imagine that an item coding for a piece of development in tulips could possibly fit into the program for building a beetle? We know how genes might move laterally among multicellular creatures as well, but will the infusions "take"?

A few firm examples have been developed for lateral transfer from bacteria to multicellular organisms. Crown gall tumors, for example, are induced in plants by lateral transfer of a tumor-inducing plasmid from the soil-dwelling *Agrobacterium tumefaciens*. Other transfers may follow the reverse route. *Progenitor cryptocides* grows in close association with certain human tumors and may manufacture, in isolated culture, a protein characteristically produced by the human gene for chorionic gonadotropin. But these two examples, though suggestive, carry no clear evolutionary meaning. They represent diseases, or pathologies, not the stable and permanent transfer of genetic material from one species to another.

As interest and evidence mount, more relevant cases of possible transfer between multicellular organisms have been proposed. M. Busslinger, S. Rusoni, and M. Birnstiel have recently presented some intriguing evidence from histone coding genes in two species of sea urchins—*Psammechinus miliaris* and *Strongylocentrotus drobachiensis*—that diverged from a common ancestor some 65 million years ago (*Embo Journal*, vol. 1, 1982, pp. 27–33). Histone genes are generally repeated many times within the genetic programs of these species. One small clone called h19, present as three to five copies for each set of chromosomes in each cell of *P. miliaris*, shows remarkable similarity to corresponding genes in *S. drobachiensis*. For one comparable stretch of DNA, a sequence 308 nucleotide bases in length, the two species differ by only two base substitutions!

Such detailed similarity between two species need not invoke great surprise. After all, genes make RNA, RNA makes protein, and some proteins are so vital to

organism's life that natural selection ight tolerate no change in an optimal quence. Detailed similarity of genetic ructure might therefore be preserved rough millions of years in separate spe-es. But these histone sequences provoke ır interest precisely because (as we shall on see) we cannot make such an argu-ent for functional conservation in this se. We need some other explanation for e astonishing similarity in two species ng separate—and recent lateral transfer a strong possibility. Three arguments pport this conjecture.

First, the detailed similarity is meas-ed at the DNA, not the protein, level. In NA, three bases code for each amino id, and in most cases the code is redun-nt at the third position—that is, a differ-t base at position three will not alter the sultant amino acid. No matter how rig-ly natural selection acts to preserve the quence of amino acids in a protein, it nnot also "protect" DNA against sub-itutions in third positions, for such muta-ons do not alter the amino acids and are erefore invisible to natural selection. We uld understand detailed amino acid milarity between two distantly related a urchin species on functional grounds, ut striking DNA similarity is a puzzle. he accumulation of "silent" mutations in ird positions usually occurs with an al-ost clocklike regularity because natural lection cannot accelerate or repress eir spread. With 65 million years of evo-tion between them, *P. miliaris* and *S. robachiensis* should not be so similar for ese histone genes.

The second point intensifies the same rgument. We may advance reasons for nctional conservation in genes that code r proteins necessary to an organism's fe. But most DNA doesn't code for any-ing so far as we can tell; it is, in technical rms, "untranscribed"—that is, not con-erted into RNA and, thence, from RNA to protein. Our 308-base sequence is so-alled spacer DNA—an untranscribed re-ion that, at most, specifies a distance etween two functional domains along a ene. We might make an argument for reservation of its length by natural selec-on. But its untranscribed sequence ould have no functional meaning and ould therefore change with great labil-y at the clocklike rate of neutral muta-ons. Again, the virtual identity of these pacer regions in two distantly related spe-ies is puzzling under conventional views f genetic evolution.

Third, the anomaly of near identity be-ween these spacer regions of *S. dro-achiensis* and *P. miliaris* has been high-ghted by results from a third species,

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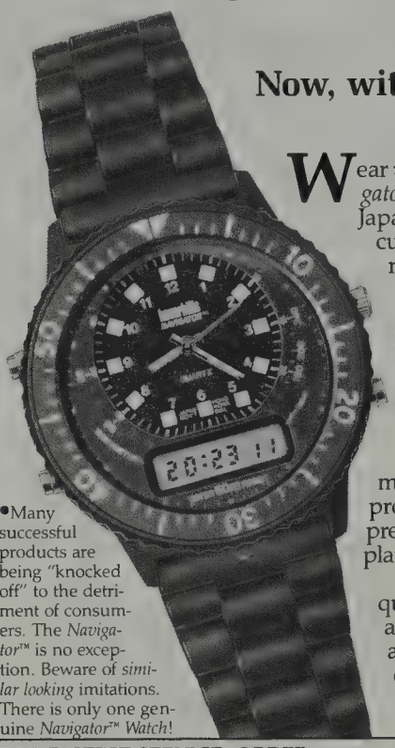

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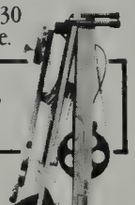

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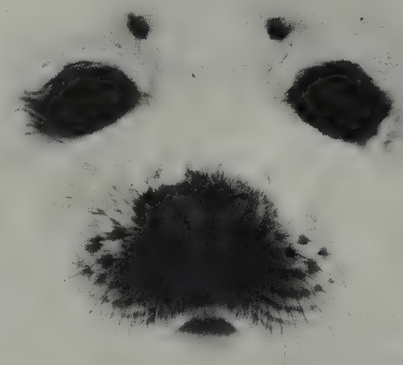

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another member of the genus *Strongyl centrotus* (about 10 million years separa from *S. drobachiensis*, compared wi some 65 million years between *S. dr bachiensis* and *P. miliaris*). The compar ble spacers of the two *Strongyloce trotus* species differ at about twenty bas (compared with two bases, or one-ten the divergence, between *S. drobachiens* and the far more distantly related *miliaris*).

This discrepancy makes no sense if g netic differences in untranscribed regio accumulate at a relatively constant rat *P. miliaris* and *S. drobachiensis* differ two positions and have been separate f 65 million years; the two *Strongyl centrotus* species differ in about twen positions and have been separate for on some 10 million years. A recent later transfer between *P. miliaris* and *drobachiensis* would resolve the parado If this histone gene has passed betwee the two species during the last few millio years, then its common ancestry is fa younger than the 65 million years separa ing the two species themselves.

If lateral transfer has not occurred, an if the spacers of *P. miliaris* and *drobachiensis* really have been separa for 65 million years, then we are forced find an argument for active conservatio against the clocklike process of rando change at the genetic level. We can co struct such an argument for transcribe proteins (natural selection for functio vital to organisms), but we have, a present, no comparable explanation f untranscribed regions of DNA. Moreove even if we could develop such an arg ment, we would still have to explain ho conservation can be ten times stronger i two species separated by 65 million yea than in another pair only 10 million yea apart.

We welcome such new and suggestiv examples but must now turn to the olde and most publicized potential case of la eral transfer—the hemoglobins of legum nous plants. Classical examples are ofte wrong, even for valid general phenomen (guinea pigs are rodents, but the world not wanting for swine). I shall argue tha lateral transfer need not be invoked explain its most famous proposed case– but that wrong examples are often mo instructive than valid claims when w strive to formulate and sharpen the prope criteria for an unorthodox theory.

Hemoglobin is the quintessential pr tein of animals—the molecule that tran ports oxygen to our tissues. Yet hemoglo bin also plays an important role in nitroge fixation within the root nodules of legum nous plants—peas, soybeans, and their a

ies. These legume-hemoglobins (called eghemoglobins for short) seem so peculiar in function, and so restricted in taxonomic distribution among plants, that several biologists have proposed an origin as interlopers from the animal kingdom by lateral transfer.

Plants need nitrogen but cannot use it in the molecular form (N_2) that dominates our atmosphere—nature's classic case of water, water everywhere, but not a drop to drink, since our atmosphere is 78 percent nitrogen. The strong triple bond between the two atoms of molecular nitrogen must first be broken; nitrogen may then be trapped for use (or fixed, as we say) in the form of ammonia (NH_3). Plants cannot fix nitrogen by themselves, but a few groups—notably the legumes—have enlisted a bacterium in one of nature's tightest and most interesting symbioses. Bacteria of the genus *Rhizobium* inhabit the root nodules of legumes. These bacteria harbor powerful enzymes that can break the triple bonds of molecular nitrogen, but this reaction can only occur under anaerobic (oxygen-free) conditions—an obvious dilemma since plants produce oxygen during photosynthesis, and the bacteria need oxygen for respiration.

Legumes use their leghemoglobin to promote nitrogen fixation in what would otherwise be an inhospitable environment. We use hemoglobin to transport oxygen to our tissues, but hemoglobin can also work in reverse to "mop up" oxygen and maintain anaerobic conditions in an otherwise well-oxygenated region. The actual functions of leghemoglobin are subtle and dual; this molecule does serve as a sink to hold oxygen and permit nitrogen fixation to proceed, but it also transfers oxygen to supply respiratory needs of the bacteria—and with a subtlety of timing and placement that does not disrupt the contradictory requirements of nitrogen fixation.

The symbiosis of bacterium and plant is intricate enough in physical proximity but becomes even more intimate in chemical terms. The leghemoglobin that regulates nitrogen fixation is a joint production of the two actors. The smaller heme unit, the active site for oxygen transport, is manufactured by the bacterium, but the much larger protein structure that cradles the heme groups, the globin molecule, is synthesized by the plant.

Suspicions of lateral transfer arose from two sources—the apparent restriction of hemoglobin to one small group of plants and the production of one key component by the bacterial symbiont. Since hemoglobins are not plant compounds, and since bacteria make the heme part of leghemoglobin, why not argue that bacteria once made the globin as well—and that globin genes have since intruded into plant DNA by lateral transfer.

This first version of lateral transfer has been effectively disproved by resolving the DNA sequence of plant globins. Bacteria and blue-green algae form simple cells without nuclei, paired chromosomes, or mitochondria—the so-called prokaryotic (or prenuclear) level of cellular organization. Other organisms, including all multicellular creatures, have eukaryotic cells with nuclei and other complex organelles. These differences in cellular anatomy are matched by disparities in the structure of DNA. Eukaryotic genes are constructed in pieces, with transcribed regions (called exons) separated by stretches of DNA (called introns) that do not code for proteins. Prokaryotic genes contain no introns.

The globin gene of soybeans was sequenced in 1981. Not only does it contain introns and exons, but two of the three introns occupy the same position as the introns of animal globin genes, while the third has no counterpart in animals but occupies a site that separates coding re-

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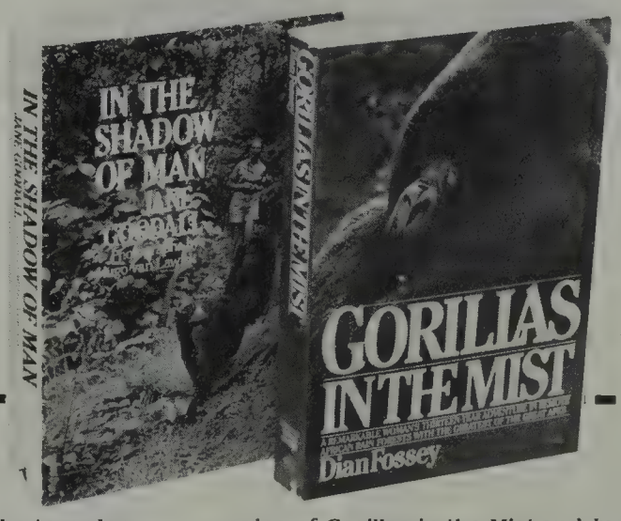

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gions for two separate structural domains of the globin protein (suggesting that animal globins once contained this third intron as well, but later lost it and spliced the two adjacent exons together, while maintaining the functional differences between their coding products). Thus, the globin gene of legumes is made from eukaryotic, not bacterial, DNA.

Yet, while the bacterial conjecture died, the close similarity of sequence between legume and animal globin genes inspired a second version of the lateral transfer hypothesis: perhaps the globin genes of legumes arrived by lateral transfer from a multicellular animal.

We therefore have two competing hypotheses: either the globins of legumes and animals are retained from a common ancestor that lived between 600 million and more than a billion years ago or globins were transferred as viral passengers from animals to plants much more recently. (The third possible hypothesis of independent evolution can be dismissed, since globins are too complex for multiple origins. Simple and necessary things, like wings in flying creatures, evolve again and again; intricate and detailed structures do not repeat themselves.)

The alternative of lateral transfer seemed attractive for two major reasons: the apparent restriction of globins to a small group of closely related plants (indicating transfer to them directly rather than deep homology in all plants) and supposed similarity in structure for a complex molecule across a wide taxonomic gap. But both reasons have been challenged by new data in the past two years.

First, the new technology that permits rapid and routine sequencing of both DNA and amino acids has provoked an explosion of information about details of genetic structure. The globin genes of several plants and animals have been sequenced during the past five years, and we now know that similarity in basic function is not matched by identity of structure. The sequence of leghemoglobin itself differs widely among species (48 percent amino acid difference between soybean and yellow lupine, for example)—indicating a long history for globins among legumes. More important, the disparity between leghemoglobins and animal globins is far greater—85 percent between soybean and most animals, for example. As discussed earlier, genetic changes accumulate in a quasi-clocklike manner—a generalization replete with exceptions but yielding a rough estimate of time from data of genetic distance. Eighty-five percent amino acid difference translates to a time since divergence from common an-

estry of about a billion years! But precursors of plants and animals split from a common ancestor about a billion years ago, and any argument for lateral transfer on structural grounds collapses. Plant globins seem to have an independent history as long as the history of plants themselves.

Second, globins have now been found in the root nodules of several plants only distantly related to legumes—in *Parasponia* of the Ulmaceae, and in *Casuarina*, a group including the Australian pine, or "she-oak." Lateral transfer was attractive when globins seemed confined to legumes—for introduction from animals might place an odd gene into ancestors of one coherent group of plants. But why propose anything but common presence by ordinary descent for a molecule that appears widely, however sporadically, throughout the angiosperms or flowering plants?

Lateral transfer of animal globins is not dead, but the hypothesis has been greatly weakened by these two discoveries. Globins for several invertebrate phyla have not yet been sequenced, so we might still argue that plant globins were laterally transferred from such an unsequenced animal. The splitting of animal phyla did not occur much later than the separation of plants and animals from common ancestry—so an 85 percent amino acid difference might record the separation of vertebrate and nematode (a prime candidate among unsequenced animals), as well as vertebrate and plant. We might then claim that the lateral transfer occurred longer ago than previously suspected—into a common ancestor of all angiosperms sometime during the Cretaceous period about 100 million years ago. Such an early transfer would explain why globins crop up in distantly related angiosperms but (so far) in no other kind of plant. I regard these two saving arguments as too much special pleading, and therefore conclude that the tide of evidence has turned against lateral transfer for the origin of plant globins.

Yet the defeat of this hypothesis would raise an issue every bit as interesting as the intriguing notion that it forced us to abandon: If globin genes are the common heritage of all plants, then why (so far as we know) are they expressed in only a few angiosperms and in connection with nitrogen fixation? What did they do for a billion years before? And what are they doing now in a hundred thousand other species of plants? Truly useless genes should be degraded to nonsense by genetic drift. Something must be preserving the globins, but that something cannot be utility in nitrogen fixation—a function for globins shared by only a few higher plants at the termini of a branch or two on the tree of botanical evolution. Just as our ears grabbed bones from an ancestral reptilian jaw, and birds and insects recruited wings for flight from their previous use (perhaps) in thermoregulation, legumes must have recruited globins for nitrogen fixation from a former and different utility. Evolution is a complex tale of such quirky changes—and the discrediting of lateral transfer might reveal an even more interesting story about functional shift during the history of globin genes in plants.

The study of lateral transfer is in its infancy. Some examples seem plausible; others, including the classical case, now seem dubious. How common might the phenomenon be? I only wish I knew. My suspicions say "not very"; my hopes say "maybe." The major argument against high frequency is a statement of simple common sense—obvious, but powerful. We have a fairly reliable Linnaean classification, at least for animals. Lateral transfer cannot be expressed in the hierarchical system of Linnaean nomenclature. If lateral transfer were rife in animals, we could never have constructed a workable classification for them by Linnaean criteria. Yet, as my colleague Hy Hartman pointed out to me, this sensible and probably irrefutable argument might be turned to suggest a potentially large role for lateral transfer in other groups. We have never been able to develop a coherent and consistent Linnaean scheme for some other kingdoms—fungi and bacteria, for example. We have attributed this failure to simple ignorance, inexperience, and a host of other difficulties in these less congenial groups—and such arguments may well be right. But high frequency of lateral transfer might also explain our difficulty as a matter of theory, not stupidity. Perhaps the working of evolution, not the limits of our mind, has frustrated the universal application of Linnaean taxonomy.

Finally, if lateral transfer were common in the history of genetic systems, then we might draw more fruitful parallels between biological and cultural evolution—an old desire now frustrated by the fundamental difference between rich amalgamation in cultural history and continual diversification in biological lineages. The quadricultural mishmash of my childhood buddy Dick Reeve, an Irish Catholic who liked chocolate-covered matzohs, might mimic the geometry for three billion years of life's history.

Stephen Jay Gould teaches biology, geology, and the history of science at Harvard University.

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Following the Pack

by Robert R. Ream

On a clear March morning last year, the thermometer frozen well below zero, I stood on a road cut a few miles north of Glacier National Park and howled for wolves, as I had many times in the northern Rockies during the past twelve years. This time my efforts were rewarded. A pack I had been following through radio telemetry howled its vivid response. At the time, the howls brought many unanswerable questions to my mind. I wondered about the group interactions that lay behind the moving chorus of howls. I wondered which wolf had initiated the response and which pack member performed each element of the song.

IN PRAISE OF WOLVES, by R.D. Lawrence. *Henry Holt and Company, $16.95; 245 pp., illus.*

No one can explain the structure of a group howl. Still, researchers go on trying as best they can to understand the behavior of these dramatic animals. Having concentrated my wolf research on wild animals, I found myself intrigued by R.D. Lawrence's *In Praise of Wolves* for its attempt to bridge the gap between field research and studies of captive animals. Field researchers depend on observational skills to track animals and on radio telemetry equipment to follow pack locations. Occasionally, and often by mistake, our efforts are rewarded by a glimpse of a lone wolf or, as happened to one of my researchers, ten minutes of watching an entire pack cavort in an open meadow. Studying captive animals, researchers learn about the specifics of wolf behavior and the personalities of pack members and can trace the rich fabric of interaction between the members of a pack. Lawrence is unique because he has spent a lifetime doing both field and captive wolf studies, and his book reflects the depth of his passion. *In Praise of Wolves* is not a popular fantasy based on wolf lore but a journey into wolf country enriched by the author's studies of a captive wolf pack in the Upper Peninsula of Michigan.

Lawrence concentrates on this pack in the first part of his book, introducing us to five wolves with characteristics as individual as any five humans. Each member in the hierarchy of this Michigan pack has a well-integrated and well-defined role, providing the basis for the smoothly functioning whole. Shawano, the dominant, or "alpha," male, exhibits clear qualities of leadership, complemented by generosity and inquisitiveness. His counterpart is Denali, an alpha female, which Lawrence describes as far more shy and retreating than Shawano. Denali could be called careful, in her movements, in the decisions she makes. The third member of the pack, Thor, is a handsome young male, jockeying with the alpha for leadership. At one point, this subtle tension erupts in a challenge to Shawano that is put down. The group clown is Toivo, in good condition but scruffy and boisterously annoying to Shawano. The least assertive member of the pack is Brigit, Denali's six-year-old mother, herself once the dominant female. She displays her low position in the pack by keeping a noticeable distance from the other members. Brigit was harassed mercilessly—chased into her den and ostracized for three days—during the breeding season. Rarely will a female that is not dominant in the pack be permitted to

Wolves at play

Photographs by Jim Wuepper

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A dominant wolf (center) threatens a subordinate

mate with either the dominant or even the subordinate male. "This is one of the inherent ways in which wolves control their populations and thus keep their numbers in balance with their food resources," Lawrence observes.

When humans enter this tightly structured wolf society to study a captive pack, they must establish their alpha status early on and continue to maintain it. Many people have gotten themselves into trouble by not obeying the rules of wolf behavior: a person who is not considered dominant will undoubtedly be challenged by the alpha wolf in a pack. As a graphic example of this situation, Lawrence describes his own wrestling match to subdue a yearling male.

All wolf biologists I know fear that the public's attraction to this animal is a double-edged sword. Sometimes the attraction can be fatal. I was glad to see Lawrence treat the subject of "wolf pets" in his book. All those who have considered such a step should read this treatise. Although it is possible to keep a wolf in the house, it will wreck furniture, doors, and whatever else it can sink its teeth into. Wolves are wild animals. There is a great deal of difference between dogs and wolves. Dogs have been slowly domesticated by humans over the centuries, but wolves are still wild. In its exuberance to greet its human packmates, a wolf will almost certainly—and not on purpose—scratch, bruise, or bite. A wolf can never be totally trusted with strangers, in large part because the stranger's behavior cannot be trusted with the wolf. "The wolf and all other wild beings are the work of nature," says Lawrence, "they are pure wild, gloriously so. That is why a wolf can never be owned; it cannot be mastered. This is not because they are intractable, but because it will not willingly submit to any rules but those that govern its own society."

I suppose that is the beauty of wolf study—humans have not yet learned all the rules of another animal society. No matter how many hours of research and observation we spend studying animals, there is still a mystery to unfold that keeps us entranced by their behavior. The lack of rigidity in wolf society reminds us of human beings; yet both maintain a strict set of rules.

Lawrence is obviously hooked on unraveling the mystery of this wild animal. His studies and travels have taken him beyond Michigan to wild British Columbia, where he treats the reader to vivid descriptions of wolf activities in the wild. He spent ten nights in a blind he constructed near a grizzly bear carcass to watch a wolf pack feed. These wolves reaffirmed the ob servations of pack interaction he had made of wolves in captivity. The same hierarchy was obvious, as well as simila interactions and behavior patterns. The first night, the pack consumed sixty o more pounds of bear meat, about twelv pounds each. The grizzly provided them with quite a feast, but wolves can weathe lean times as well—they have coevolved with boom-and-bust ungulate populations

The longest continuous study of wolve and wolf–prey relationships has taken place over a thirty-year period on Isle Roy ale, near the Upper Peninsula of Michi gan. Lawrence takes us there in his book in fact, no discussion of wolf research would be complete without mention o this fascinating, decades-long study Durward Allen of Purdue University initi ated the studies at Isle Royale, and his students have continued to maintain the high standard of research he began in 1940. The story that has unfolded at Isle Royale is an important one for all con cerned with wolf survival.

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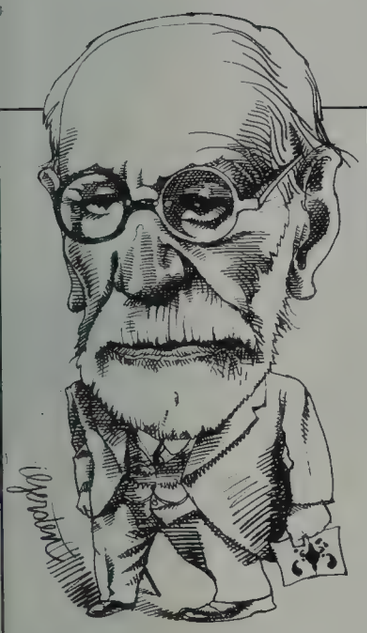

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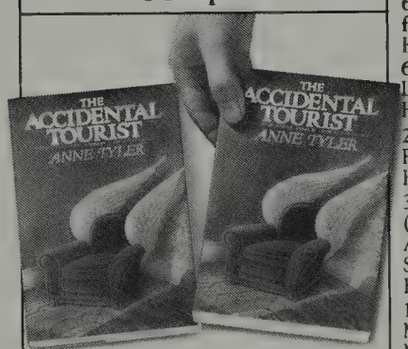

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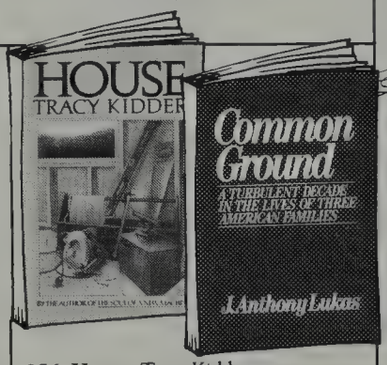

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arrival of the wolves, the moose population fluctuated wildly. After the wolves came, a balanced predator–prey relationship was reached, and the boom-and-bust cycle of moose populations ended. However, Biologist Rolf Peterson's work during the past decade has shown a crash in the wolf population following a decline in moose. Peterson now believes the system of Isle Royale to be cyclic; about every twenty-four years the moose population reaches a low point, which is followed some ten years later by a decline in wolves. Long-term research, such as this on Isle Royale, is the only kind of work that can fit together the complex pieces of the wolf puzzle.

Among the most fascinating details that emerge from Lawrence's work are his observations on the relationship between the raven and the wolf. In Glacier National Park this winter, I heard wolves and ravens calling back and forth and can agree with Lawrence that "nothing is more haunting, spiritual, and primitive than the calls of ravens and wolves coming at the same time from the same location, a wild concert not infrequently heard during the breeding season of wolves and after a pack has made a kill." He goes on to trace the raven–wolf relationship in other cultures. "The Indians and Eskimo of North America certainly recognized this strange affinity, for their legends often couple the bird and the mammal, both of which were also endowed with spiritual or even godlike qualities. More than a few clans adopted either the wolf or raven, sometimes both, as their special totems; individuals saw one or both animals in dreams induced by sweat baths and fasting, and then accepted them as alter egos."

In Praise of Wolves is a delightful step toward understanding a complex and absorbing animal. I would, however, have liked more references throughout the text, so that the reader could pursue particular areas in more depth. Unfortunately, Lawrence also ended his book with a strong attack against hunting and hunters in general. As a field biologist, I know how gingerly we must tread the fine line between the various attitudes of the human popula tion toward wolves. Many hunters hav proved themselves to be true sportsmen however, and these same sportsmen ca be educated to be our strongest supporter of wolf recovery. In the western Unite States at least, we can't attain wolf recov ery without the help of this segment of th population. Lawrence's book shows hov difficult it is to be objective. We must b delicate in our approach to bringing thi animal back among us. For, as Aldo Leo pold said, "Only the mountain has live long enough to listen objectively to th howl of the wolf."

Robert Ream has been a professor at th University of Montana School of For estry for the past seventeen years. Sinc 1973, he has headed the Wolf Ecolog Project in Montana and has documente the beginnings of wolf recovery in th northern Rocky Mountains. He has als been a member of the Northern Rock Mountain Wolf Recovery team since it inception in 1974.

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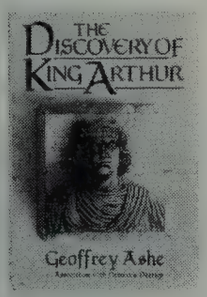

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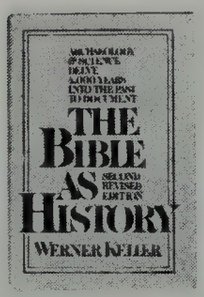

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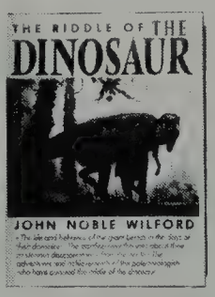

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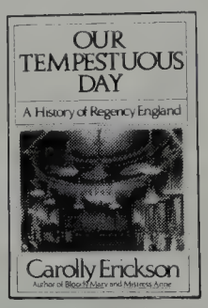

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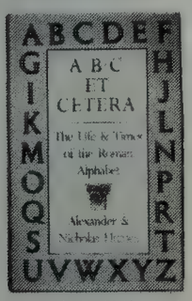

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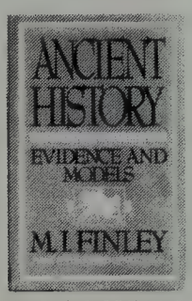

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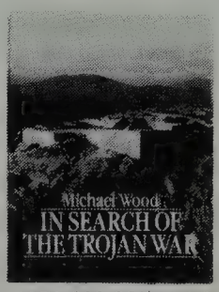

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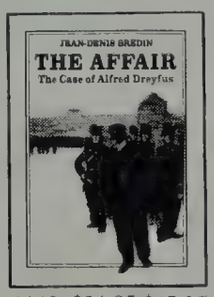

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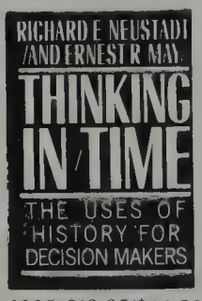

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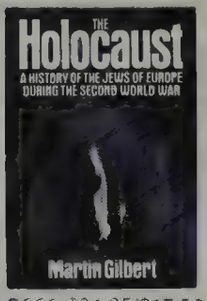

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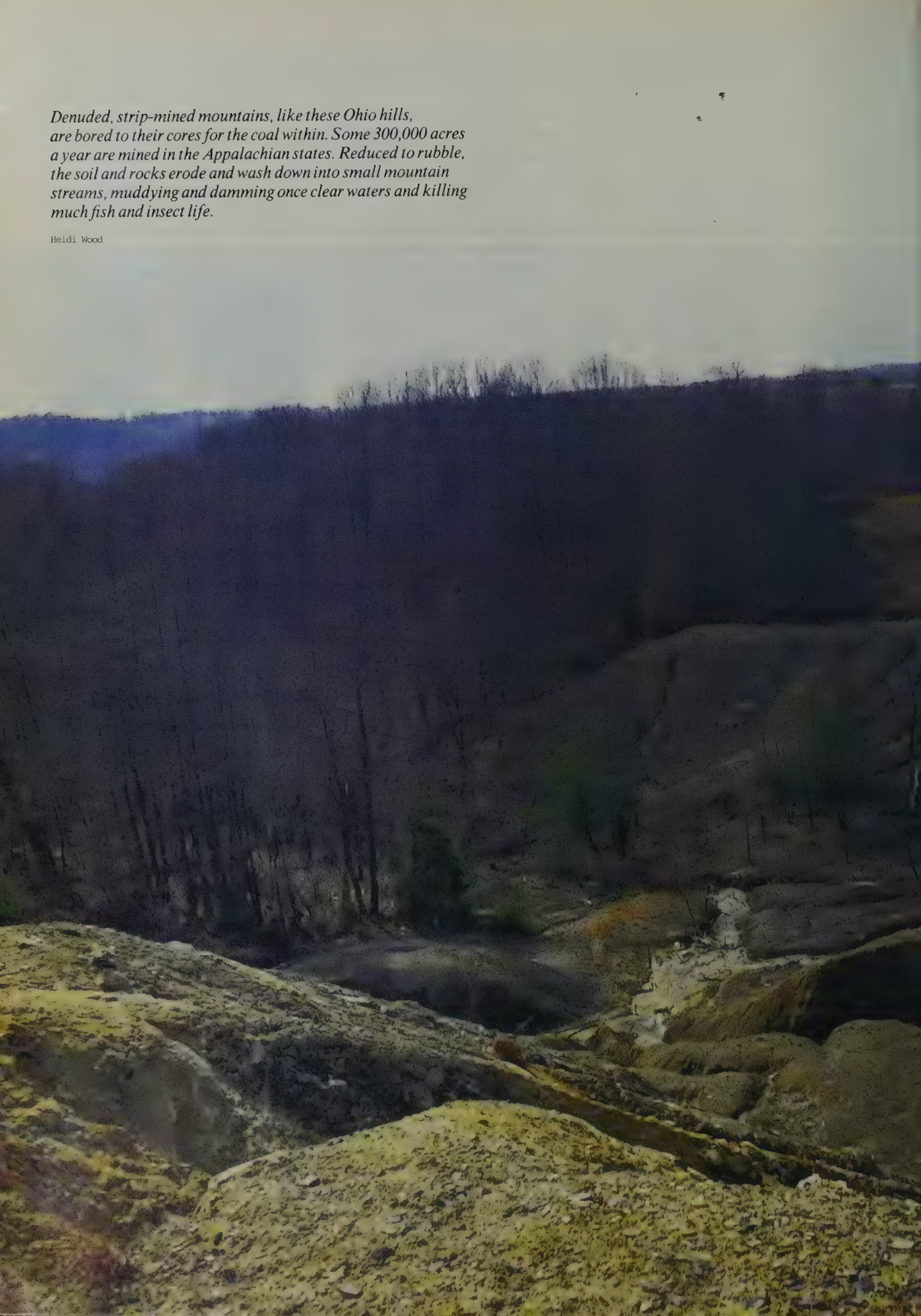
Denuded, strip-mined mountains, like these Ohio hills, are bored to their cores for the coal within. Some 300,000 acres a year are mined in the Appalachian states. Reduced to rubble, the soil and rocks erode and wash down into small mountain streams, muddying and damming once clear waters and killing much fish and insect life.

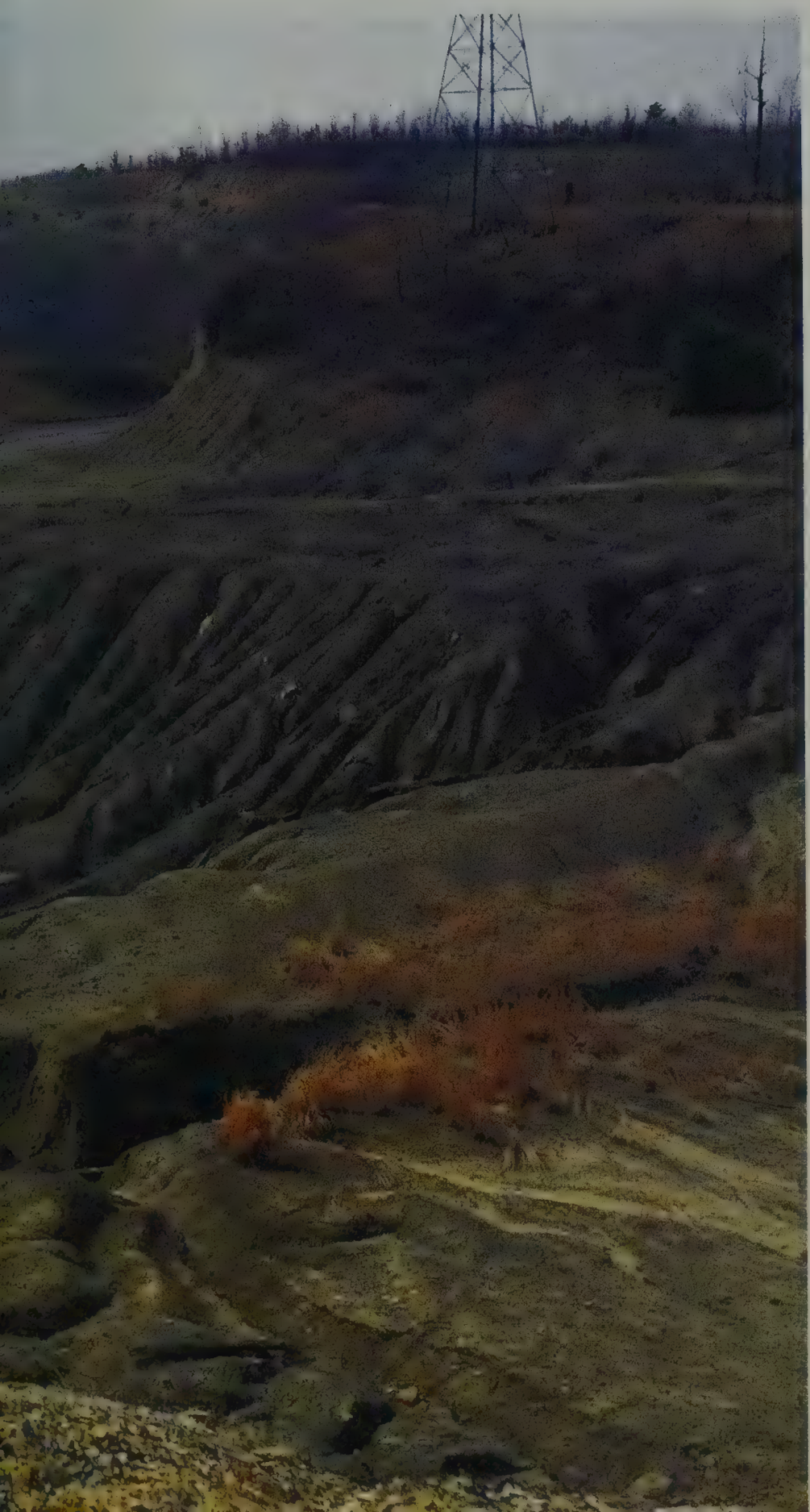
Heidi Wood



Is There Life After Strip Mining?

For the insects and fishes in small mountain streams, the problems linger long after the mining stops

by Branley Allan Branson



The area into which we drove had been blasted, and the forest ravaged beyond recognition. We turned our dust-covered pickup truck this way and that, avoiding slabs of rock lying at awkward angles and crossing erosion gullies trickling with orange-and-red water. At the point where the hillside tilts up against layered sandstone slabs and mud, we came to the mouth of a small creek. Shaded by heavy-boughed hemlocks, rhododendrons, ironwoods, and laurels, it had once flowed crystal clear from pure springs beneath the sandstone. Now it was a barely moving rivulet of mud. We drove up the channel until the way was blocked by the boles of fallen tulip poplars. We left the truck and continued up the mountain on foot.

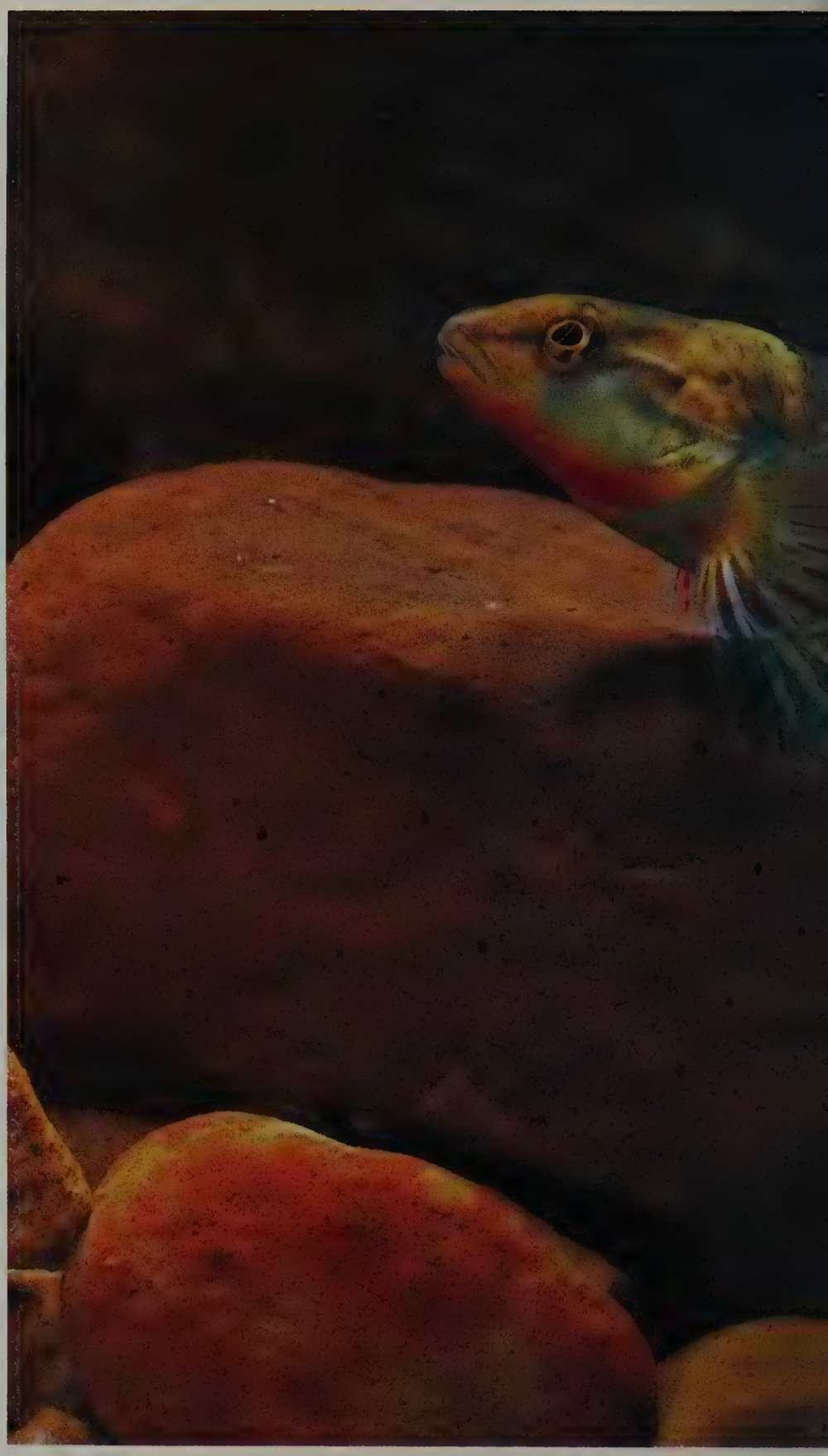
The creek was only fifteen feet wide, and as we worked our way toward its source, the air turned cooler beneath the dense, overhanging vegetation. Soon the sky was blocked out altogether, and the gritty mud made footing precarious. At the end of the tunnel of healthy vegetation we could see the treeless landscape beyond. Our hike had brought us to the top of a beheaded mountain whose devastated slopes were typical of hundreds of strip-mine sites in the Appalachians. There was no longer mining activity here, and in the stream bed we searched diligently beneath stones and debris for any signs of biological recovery. Flat-bodied mayfly nymphs scurried away from the light, and water striders, their feet scarcely breaking the surface film, retreated from the disturbance. There was evidence of a general increase in living things in that silt-laden rivulet, but much was missing.

We knew this area well, for since 1969, Donald Batch of Eastern Kentucky University, some associates in the U.S. Forest Service, and I have been studying the influence of surface mining on the chemistry and animal life of this and other small streams in east-central Kentucky. (Details of our early work were presented in *Natural History,* November 1974.) These small streams once contained diverse animal communities. Moreover, each was a balanced community in which the small organisms that lived on the stream bottom and the plants that lived in the stream bed

Below, top: The confluence of a silt-loaded stream and a clear-water tributary. Where the stream slows, silt settles and turns the rocky stream bottom to a sandy one, suffocating or burying much of the stream life. Bottom: Some mines produce acid drainage. The acid is the result of the oxidation of iron and sulfur found in eroded soils.

Raymond A. Mendez

Kent and Donna Dannen



and banks supported a variety of insect life that, in turn, supported fish, amphibians, and the local terrestrial animals—minks and raccoons—that feed on fish.

The critical factor that supported life in the stony headwaters of these streams was a flow of water sufficient to provide a continuous supply of oxygen. The critical feature of strip-mine ecology is the massive amount of silt washed down into streams from banks of eroding spoil, so reducing the flow of the stream that practically none of the original habitats of the stream bottom remain. In the first six months of strip mining, sediments in once clear streams can accumulate to depths of eighteen inches or more. Very soon after there are no mollusks—clams or snails—left in the streams. Fish are deprived of the bottom-dwelling insects and crustaceans upon which they feed and are forced downstream as silt clogs the coarse cobble gravel on which they spawn. Eggs and fry are smothered by silt.

Our studies of these streams show that after seventeen years fish populations have made only minor advances toward recovery, with many species absent altogether. Darters, which are bottom feeders and breed amidst the gravel, were the first to be affected. The bluntnose minnow, however, which lays its eggs close to the surface and feeds there as well, was able to survive. Reduced competition among fish has made it easy for a species like the creek chub, which is capable of feeding from the surface of the water and so is resistant to the effects of siltation, to undergo a population explosion in streams that once supported a balanced mix of species. A stream ought to be judged by the balance among its components, how the water and its dissolved oxygen and nutrients support plant life, predators, and prey. Neither a diverse selection of species nor the successful domination of an environment by one species indicates a healthy stream environment. Cursory surveys of

Alvin E. Staffan

Fishes, such as the rainbow darter, left, are obvious victims of stream siltation. But the larvae of insects, central to the food chain of a small stream, are also often among the missing. The damselfly larvae, below, live in the water and breathe through very fine gill filaments, which are easily clogged by silt.

Raymond A. Mendez

streams may therefore not demonstrate the real impacts of strip-mining pollution.

Some mines produce acid and other types of pollutants, but all mines create siltation. With the forest cleared to get to the coal, the surface materials known as overburden—topsoil, subsoil, sandstone, clay, and sand—are subject to erosion. Rock and soil are transported by rushing waters or are held in suspension and deposited downstream wherever the flow of water slows, such as where streams widen or form backwater pools. Even after the initial stages of mining pass, sedimentation poses problems for streams. For many more years, the runoff after heavy rains can be thick with fine-grained, stream-clogging material. The result can be that the water-carrying capacity of headwater streams is reduced by two-thirds or more. By comparing Jenny Fork, a small creek never involved in mining, with the afflicted streams—Leatherwood, Miller, and Mullins creeks—we were presented with classic pictures of what happens to waters that are polluted by mining. Surface mining ceased in these drainages in 1972, with only Mullins Fork suffering from additional work from 1978 to 1981. Just after the onset of mining, both the kinds and numbers of all aquatic organisms fell drastically.

We have since found that the organisms most indicative of long-term changes in the stream are the aquatic insects and crustaceans. The mayflies and stoneflies, for example, are central to the balance of these small streams. They are known as primary consumers, feeding on smaller organisms and, in turn, being fed upon by spiders, fish, birds, and larger insects such as dragonflies. Most of their lives, though, are not spent flying (the mayfly's flying life can be as brief as a few hours, as its scientific name, *Ephemera*, indicates) but as aquatic naiads anchored to the stream bottom. In this long stage of their lives, they breathe through gills and depend for

their survival on clean, cool, swift-moving currents, which bring them both oxygen and a continuous supply of food in the form of bits of leaves, algae, and smaller animals that drift their way. These flies have evolved a variety of methods for anchoring themselves in the strong stream currents. Some forms of mayfly burrow into river bottoms, others have a flat underside that allows them to lie close to stones, and still others anchor to stones by suction. Since cold water holds more oxygen than warm, the species that live in cool headwaters tend to have small gills easily clogged by silt. Silt-thickened water will also interfere with the feeding of the naiads of both mayflies and stoneflies, and silt accumulations will bury them. We found these insects were eliminated during the course of mining and have apparently been unable to reestablish colonies; the few that have returned are there in numbers considerably lower than in 1968 and 1969.

Midges, small aquatic flies whose various groups make up a large part of the insect life of a stream, were also casualties of siltation. The larvae of some groups, although they move along the stream bottom, have large fanlike breathing structures and digestive tracts easily clogged by fine silt.

Caddisflies, though their populations

were severely reduced, show how siltation can affect one species and not a related one. The caddisfly genus known as *Helichus*, usually abundant in mountain streams, has not been seen in these streams for ten years. At the same time, *Hydrobius*, a related genus, and usually far less abundant, survives. The difference is simply that *Hydrobius* larvae have a less delicate breathing apparatus, along with the ability to get up on top of rocks

Alvin E. Staffan

The dobsonfly larva, or hellgramite, left,is a voracious predator that moves freely among rocks in the stream. It is not so readily extirpated by siltation. While many organisms survive in streams affected by strip mining, the natural balance of species can be severely disrupted. In the absence of mayflies and stoneflies, whose larvae cannot survive in the much altered stream, waterstriders, below, invade.

Raymond A. Mendez

and escape being smothered by the silt. Similarly, since they normally live among coarse stones and rubble and are very active hunter-predators, dobsonflies are more or less resistant to silt pollution. Aquatic beetle larvae, however, are gill breathers that live under rocks and are choked by silt. Dragonfly larvae need high concentrations of dissolved oxygen and cannot make it. By allowing resistant forms to gain control and by removing competition, habitat-modifying influences produce unbalanced communities.

The heteropod insects, waterstriders, for example, were not found at any of our collecting sites from 1968 through 1970. After 1970, five related species began to appear in the collections. We believe that the massive sediment loading of the streams slowed the current, creating several sluggish, ooze-filled pools and changing the habitat to one that allowed these animals to colonize the streams in the absence of mayflies and stoneflies.

In streams, insects colonize new territories by drifting either upstream or downstream. Although upstream migration is only 5 to 30 percent as effective as downstream migration in repopulating decimated areas, it is nonetheless an important phenomenon. The change in the stream bottom from a cobble-gravel makeup to a sandy-silty one often precludes active upstream migration by many aquatic insect larvae, such as stoneflies or other insects whose flat bodies and clawed limbs enable them to move among gravel and rocks. By contrast, larval insects that build heavy cases, caddisflies, for example, have their ability to migrate upstream enhanced by sand and silt. These larger insects have hairy legs adapted for moving on silt.

Insects have also proved a good indicator of the chemical changes associated with mining. Such changes can only be measured over a period of years. In 1968 we began monitoring many of these compounds as suspects in long-term perturbation of biological communities.

The removal of surface vegetation and soil preparatory to mining exposes the underlying rock to erosion. These rocks contain sulfur, which is oxidized into sulfates by exposure to rainwater. The sulfates are compounded with calcium, magnesium, and iron, which are also found in the eroded material. While it appears that at high enough concentrations these compounds will interfere with the nutrition and reproduction of stream organisms, measurement of these substances, along with their specific conductivity, is of great importance to understanding the long-term degradation of these streams. (Sul-

fates enhance the ability of stream water to conduct electric currents and so measurement of specific conductivity can be used to determine a stream's pollution.) In most small Appalachian streams, exemplified by the conditions in Jenny Fork, sulfate concentration ranges from about 20 parts per million (ppm) to 50 ppm, even during peak storms. Almost immediately after mining begins, sulfates are generated. The amount gradually increases, and in drainages where the disturbed overburden is rich in sulfur-bearing minerals, the long-term production of sulfates can attain levels higher than the 250 ppm in Leatherwood Creek.

A similar picture is seen in the production of calcium and magnesium. Undisturbed Jenny Fork exhibited only seasonal fluctuations of these substances. By contrast, Leatherwood and Mullins creeks showed an exponential increase in both substances during the postmining years, calcium reaching more than 80 ppm and magnesium 50 ppm by 1982.

As these chemicals increase in stream water there is a general trend toward poor biological populations, particularly in streams impacted by high sulfate and hardness concentrations. And although all organisms are affected, the larval insects, along with small crustaceans and mollusks, are most affected because they are unable to escape the cumulative effects.

Prior to the mid-1960s, most surface-mining projects were designed around the cheapest means of removing coal and usually resulted in exceedingly heavy water pollution. While recent legislation has forced mining engineers to seek ways to minimize pollution, the serious shortage of federal and state mine inspectors, the failure to enforce laws, and a lack of environmental ethics on the part of many miners continue to insure adverse conditions in much of Appalachia afflicted with mining. Our work shows that aquatic faunas are severely affected by coal mining and that recovery, if it comes at all, is a very slow process. Humans downstream, living on the edge of their own environmental tolerances, may be unaware of the ecosystems that are falling one by one in the distant mountains. □

With the darters gone, the creek chub, below, goes unchallenged for food and space, and its populations surge. Because the creek chub is capable of feeding from the surface of the water, siltation left its food supply unaffected.

Raymond A. Mendez

Raccoon dogs rest by day under an oak
Hans Reinhard; Bruce Coleman, Inc.

Old Dogs, New Treks

Asia's raccoon dog, a venerable member of the canid family, is pushing into new frontiers

by Hiroshi Ikeda

Imported from the Far East in 1927, raccoon dogs thrived in western Russia and pushed into new territory with steady momentum. Scandinavia was the first region of Europe to see them: Finland in 1935; Sweden in 1945. Radiating south and west to Poland, Hungary, Romania, and Czechoslovakia in the 1950s, raccoon dogs predictably ventured into Germany and Austria in the 1960s, and reached the front line in France in 1979. Few Americans, however, have made the acquaintance of the raccoon dog or know it only as a fur on a rack. Known in my country as *tanuki,* this mammal, which plays a role in the cultural as well as the natural history of Japan, has been the focus of my studies for the last ten years.

Although its pointed muzzle, dark mask, short legs, and bushy coat give the raccoon dog a superficial resemblance to the raccoon, the two are not closely related. The seven-to-twenty-pound raccoon dog is a member of the Canidae, or dog family, and represents a single species, *Nyctereutes procyonoides,* which is divided into six subspecies. Rather primitive and solitary canids, raccoon dogs never form packs, a social structure associated with later-evolving canids such as wolves. Considerable attention has been given to the most strictly carnivorous pack-hunters, but few studies of solitary omnivorous canids, such as the raccoon dog, have been undertaken.

Present-day canids evolved in North America and migrated across the Bering land bridge to Asia in the late Pliocene epoch, about two million years ago. The ancestor of the raccoon dog, however, took the bridge west even before the other Canidae members fanned out. Its natural distribution is confined to the Far East: eastern Siberia, Japan, parts of China, and northern Indochina.

Why—despite being hunted for its pelt, persecuted in Europe as a pest, and constricted in its natural range, now heavily populated by humans—has the raccoon dog remained so tenacious a species? I believe the answer lies in the animal's great physical and social adaptability.

I began fieldwork in February 1976 on an islet near Kyushu, the southernmost main island of Japan. This part of my study lasted for two years. Each day I traced tunnellike paths into the heavy undergrowth of deciduous forest and collected fecal samples. The analysis of scats is important because it supplies information about an animal's diet. A peculiar habit of raccoon dogs makes feces collection relatively easy and eventually helped provide a key to this canid's basic social structure: raccoon dogs defecate at "latrines," particular sites within their range. Latrines were distributed throughout my entire study area but were often located on ridges and peaks. A common latrine measures ten to sixty inches in circumference, and its mound of accumulated feces may be six inches high.

My analysis of their deposits revealed that raccoon dogs are true omnivores, eating an array of foods—mammals, birds, fish, reptiles, insects, crabs, fruits, berries, and acorns. Anything edible within their range was likely to turn up in their scats at some time. I found that the proportion of different foods changed with the season and corresponded to the availability of resources. Of their two favorite foods, fruit was eaten most often in the spring and fall and insects in the summer. In these seasons, feces consisted either of lumps of seeds or fragments of insects.

Manabu Miyazaki; Nature Production, Tokyo

A common sight in Japan, raccoon dogs can survive near cities and have been known to den under houses. A foraging parent and pup, right, will return to a yard every night if scraps are available. Raccoon dogs are endemic to the Far East (green crosshatching, below). In the 1920s, a Siberian subspecies was introduced into western Russia (green and yellow crosshatching, below) for the fur trade. From there, the raccoon dogs have spread steadily north and west into Europe.

Joe LeMonnier, after Heptner, VG, Naumov, NP (eds.) *Die Säugetiere der Sowjetunion* (Jena: Gustav Fischer Verlag, 1974)

Mammals, birds, invertebrates other than insects (centipedes, for example), and acorns made up the winter diet. In my study area, marine organisms, including fish and clams, accounted for much of the raccoon dog diet year-round. Nonspecialization enables raccoon dogs to shift their intake in response to food availability. They can find suitable fare in any season and in almost any habitat.

One drawback of the raccoon dog's feeding ecology is its dependence on food in small packages. Because of this, raccoon dogs must spend a long time each night searching for food. Within two hours of sunset they begin to forage. After a break about midnight, they are active again until sunrise. Although they eat small mammals such as voles and mice, as well as birds, raccoon dogs are not skillful hunters of larger prey; even when searching for earthworms, they zigzag, plunging their snouts into the undergrowth and sometimes scratching the ground. Only when the earthworm presents itself right in front of a raccoon dog's muzzle is it nabbed and devoured.

Even this apparent liability, perhaps due to poor eyesight, is not a great hindrance. Other foods are concentrated at particular spots. Certain trees, for example, supply an abundance of berries, a preferred food, on a steady basis during the fruiting season. All the raccoon dog needs to know is where these trees are. Evergreen and deciduous forest undergrowth, stream and marsh areas, and the beach are all potential sources of food. Within these habitats, the raccoon dog is an opportunistic hunter-gatherer.

Raccoon dogs are resilient and can live in climates ranging from subtropical to subarctic. Only in the coldest of the geographical areas does low temperature force them to conserve energy by decreasing activity in the winter months. In cold regions, particularly in the northern U.S.S.R., wolves, lynxes, martens, and eagles may prey on raccoon dogs, but I did not observe such predation in Japan.

Raccoon dog home ranges are relatively smaller—from 20 to 125 acres—than those of other omnivores and often overlap extensively. Within the range, heavily used areas, such as foraging and denning places, are connected by a series of paths. Knowledge of all potential food sources inside the small range is a practical advantage. Moreover, if food sources such as fruiting trees are plentiful, many raccoon dogs may use them without detracting from the foraging efficiency of any one dog. I frequently observed such communal use of rich feeding areas.

During my study, I needed to observe raccoon dogs closely to understand their ecology, but the dense cover of their natural habitat made such scrutiny difficult. In October 1980, I began to watch raccoon dogs at a garbage site in Ebino Height in southern Kyushu. Although not a pristine natural setting, the garbage site provided data on social interactions among raccoon dogs.

I witnessed both friendly and aggressive encounters. The typical friendly scenario might begin with a raccoon dog roaming in nearby bushes, then slowly approaching the garbage site. It looks around nervously, sniffing the air with its nose up to detect any threat. After a few moments, it starts to rummage for edible refuse. Suddenly, another raccoon dog rustles out of the bush. They size each other up, slowly closing the distance be-

tween them. The newcomer extends its nose and touches the other's in greeting. Following nose contact they groom each other, licking the lips, muzzle, and around the facial mask. Mammalogist D.G. Kleiman, who has studied the social behavior of carnivores, believes the dark facial mask helps to focus attention on the face in social grooming situations. After the mutual grooming session, the two eat side by side. On the roster of dogs that fed at my Ebino Height observation post were several cliques whose members demonstrated especially sociable behavior toward one another, appearing at the site together and sharing the scraps amicably.

Body language also indicates less cooperative behavior. In such an encounter, each animal, with ears erect, back arched, and tail bent into an inverted J, directs its slightly lowered head toward its opponent. The two produce sounds just like the hiss and spit of cats. Exaggerated back arching, leg stretching, and hopping toward the adversary signal escalation. Biting and serious fighting may ensue. The beaten dog will take a submissive posture, flattening its ears, gaping its jaw, and at times even lying down with a whine. This gesture usually defuses aggression in the stronger dog, and fighting ceases.

The number of raccoon dogs congregating at the garbage site increased in the fall. By October, I could identify thirteen animals by their coat color patterns. From the friendliness or antagonism of their meetings, I was certain that raccoon dogs live in some kind of subgroups composed of from three to five individuals. I distinguished several of these subgroups at the garbage site. But by December, for reasons I could not explain, the site grew crowded with about twenty dogs. They foraged independently but tolerantly, and no aggression erupted. The group formations I had observed in October seemed to have dissolved.

With winter's end, antagonism increased among the animals frequenting the garbage site. I knew that spring had arrived when I witnessed the first mating in March. One raccoon dog emerged from the forest while another, a male, was already feeding at the refuse heap. The male took an aggressive stance, but after scenting the intruder—which turned out to be a receptive female—he mated with her. Several minutes after he mounted the female, positioned with her hindquarters to the ground, the male turned his body, and copulation continued with the raccoon dogs in a back-to-back position. The tie lasted for about five minutes.

Gestation is completed in sixty to sixty-five days. Unlike foxes, raccoon dogs do not excavate dens but simply make use of ready-made shelters in rock crevices and tree hollows, under exposed roots or dense cover, and even under houses. In my study area, I tried to find the shelters containing newborns but always failed. Therefore, I decided to observe parents and offspring in a captive setting—a fenced outdoor area at Kyushu University.

During the spring I watched a captive pair court and mate. In mid-May, the female delivered five pups. The usual litter consists of four to six but can exceed twelve pups. The tiny newborns are covered with soft, dark fur. After weaning at about thirty days of age, the pups grow rapidly; guard hair, underfur, and the typical facial mask become apparent, and the handsome young look like miniature versions of the adults.

The male guards the female during delivery and helps care for the young from that time on. He brings food to the female and relieves her at the den when, after a few days, she first leaves the pups. He gently grooms the young, licking their groins to stimulate excretion. Waste is consumed by both parents. During the first thirty days, the mates share parental duties, never leaving the pups alone.

Between the age of thirty and eighty days, pups venture outside the den, always attended by at least one permissive parent. In the tradition of puppies, they play hard at running, wrestling, pouncing on imaginary prey, and perfecting the mock attack. Their father is a favorite target, allowing the pups to climb on his back, bite his tail, and then rest beside him. As the pups grow, play becomes even more exuberant and athletic. At eighty days, the young are nearly the size of their parents.

The initial development of raccoon do pups is clearly divided into two stages an takes place in summer, when food is mos plentiful. During the suckling stage— from birth to thirty days—rapid physica development takes place; from thirty t eighty days, under parental guidance, th young develop the behavioral repertoir required of full-fledged raccoon dogs.

I went back to my study site ready t piece together all the fragments of rac coon dog life I had observed in captiv settings and in the wild. In early July, pup about fifty days old shyly visited the ga bage site for the first time. In late Augus the close association between parents an mature offspring lessened, while the bon between the parents remained stable. Th group formation I had observed in prev ous Octobers at the garbage site corre sponds to this stage of family life—togeth erness, with pups maturing. The drasti

Manabu Miyazaki; Nature Production, Tokyo

Although very severe weather can force raccoon dogs to remain in dens or hollows for a few days, the thick-coated mammals are active throughout the winter in most of their range. At left, an adult crosses a stream on a nocturnal feeding foray. Siblings, below, about ninety days old, deposit their feces at a communal "latrine." Young, born in May, use the same latrines as their parents until they become independent in late fall.

Toshihiko Fujimoto; Orion Press

hange in social contact each Decem-
er—a greater number of dogs acting in-
dependently—is due to some pups having
lispersed. Thus the raccoon dog follows a
early pattern of pair formation, intense
hen gradually loosening family ties, and
inally dissolution of the family as a unit
nd a more solitary existence. Male and
emale pups establish their own ranges
when family ties slacken; however, they
re often allowed to stay around the par-
nts' ranges until the next breeding sea-
on. Although I do not yet have conclusive
vidence, I suspect that established pairs
ersist from year to year.

Although raccoon dogs are nonbelliger-
nt, even neighborly animals, the basic
ocial unit is the pair bond. Raccoon dog
ocial structure has long eluded research-
rs because the animals roam individually
even when they are part of a pair or a
family group. Moreover, as I had observed, ranges greatly overlap and certain food resources are shared.

The latrines have an important function in the social life of raccoon dogs. Seventy-eight were distributed throughout my study area; their sites and numbers were fairly stable during the period I observed them. Although the range of an individual dog may include many latrines, the animal uses only about ten within its range in a season. The distribution of latrines used and the number of feces at each site changed seasonally. I discovered that availability of food determined which latrines were used in each season and that raccoon dogs may use them to orient themselves within their range. Researcher Itsuko Yamamoto found that a raccoon dog is able to distinguish between its own and another's scats and suggested that latrines serve as information sites.

I divided latrines in my study area into two or three groups according to their pattern of use. Some latrines within a group were used communally by several raccoon dogs. These dogs shared more than 40 percent of the total number of them. The formation of these groups of latrines and the number of raccoon dogs using the same ones varied seasonally in relation to the dogs' annual life cycle. The highest degree of communal use and selective use of latrines was observed in May at the height of the breeding season. Beginning in July, when pups are about fifty days old, they deposit their feces on their parents' latrines, but they use others independently in October. Raccoon dogs do maintain pair and family bonds, in spite of their solitary movement. In addition to their probable role as landmarks and information sites, latrines also reinforce family ties.

In Japan, the raccoon dog is as familiar an animal as the raccoon itself is to most North Americans. Children grow up hearing fairy tales and folklore about raccoon dogs. A popular folk belief holds that they gather in the full moon and play music, beating their big balloonlike bellies as if they were drums. (Children are sometimes disappointed when they see actual raccoon dogs, which have flat bellies.) In many stories the raccoon dog is depicted as a dull-witted but endearing character and serves as a contrast to the sly fox. It is portrayed as a would-be trickster, able to change shapes and eager to bewitch humans, though it always fails to win in the end. Pottery figurines known as "sigaraki-yaki" are popular Japanese caricatures of *tanukis*. The animals also crop up in folk sayings. Rather than "Don't count your chickens before they hatch,"

Hans Reinhard; Bruce Coleman, Inc.

Like the adult savoring grapes, below, raccoon dogs sometimes climb trees to avail themselves of fruit. Raccoon dogs are omnivorous hunter-gatherers, opportunistically eating an array of small food items. At right, adults rummage through leaf litter, searching for acorns, worms, and insects.

Toshihiko Fujimoto; Orion Press

the Japanese caution: "Don't count tanuki pelts before they are caught."

The raccoon dog is a common animal in Japan, often found near human habitation. Even in the big city, one can spot raccoon dogs if there is a nearby patch of woods. Because of their unspecialized ecology, raccoon dogs are more tolerant of urbanization in Japan than are other wild species such as foxes and Eurasian badgers. Finnish researchers Pirkko Viro and Heimo Mikkola have suggested that the raccoon dog has succeeded in Scandinavia by scavenging for carcasses during the long winter. Unfortunately, in these northern countries—and as is often the case with transplanted species—the raccoon dog is seen as more of a nuisance than a success story. Although they have been reported to be a threat to game bird and hare populations and to domestic poultry, raccoon dogs are more likely to eat small prey, the size of small ground-dwelling birds, for example. In Japan, they consistently prefer small food items.

About 70,000 raccoon dogs are caught each year for the fur trade. Although a population census has not yet been taken, a recent distribution survey, conducted by finely dividing the entire country into districts, found the raccoon dog to be present throughout Japan. There were very few districts in which the raccoon dog population appeared to be depleted. Two factors may contribute to this tenacity. The first is the raccoon dog's high rate of reproduction—large litter size and the ability to breed at the end of the first year. The second is its great adaptability—omnivory and unspecialized ecological requirements. These have stood the raccoon dog in good stead in Japan and helped it proliferate abroad.

The major characteristic of some canids' social organization is the pack, which allows for strong bonding and for hunting large prey on open land. The omnivorous raccoon dog, able to survive on a variety of small food items, does not require such a broad, cooperative social system. Its own social order, based on the pair bond, is a stable one that promotes the efficient use of food resources. In the sequence from the forest-dwelling canids to open-range, pack-hunting canids, raccoon dogs take a place toward the beginning. They are perhaps less vulnerable to changes brought about by man than are canids with more complex and fragile ecologies. A durable social system has helped the raccoon dog to weather cities, exportation, and hunting, so far. Its natural history is a story of the nonspecialist as survivor. □

In their coniferous forest habitat, Chrysoperla downesi *lacewings often rest among pine and spruce needles with their heads toward the twig's axis. This may make them less visible to potential predators.*
Raymond A. Mendez

Good Vibrations

The way to a green lacewing's heart is through its abdomen, but the beat has to be right

by Charles S. Henry

When we think of singing insects, images of melodious crickets, rasping katydids, crackling grasshoppers, or buzzing cicadas come to mind. In our everyday experience, insects that communicate through acoustical channels are relatively large and robust. Long-distance singing is an energetically expensive business, not undertaken lightly by small, fragile insects. Yet less ostentatious singing insects do exist, calling quietly over distances of inches rather than thousands of feet. Such behavior has been described in diminutive plant and leaf hoppers, powder-post and long-horned beetles, worker ants and parasitic wasps, exotic cockroaches, drumming stoneflies, wallpaper book lice, and even submerged water scorpions.

Even so, it is hard to imagine less likely singers than green lacewings—small, delicate creatures belonging to the worldwide family Chrysopidae in the ancient insect order Neuroptera. Lacewings—their gauzy wings the very essence of frailty—possess no obvious scrapers, files, or tymbals for generating sounds. They do, however, produce signals, and in a most unusual way, by vibrating their abdomens. Indeed, the members of at least one large group of green lacewings, the genus *Chrysoperla*, depend so completely upon singing with their sexual partners that mating is normally impossible without a properly executed duet. Furthermore, it is even possible that the singing behavior of these insects is responsible for the impressive proliferation of species within the genus—species that in many cases resemble each other so closely that entomologists have trouble telling them apart.

North America is home to two of the better known of such "sibling" species. *Chrysoperla plorabunda* is a common lacewing of fields and meadows, where its pale green color often makes it hard to see as it flits about in the vegetation. This species is generally found at lower elevations, but it also occurs in clearings higher up. There, its range may overlap with that of *C. downesi*, an inhabitant of coniferous forests; the latter species' darker, more vividly green coloration may mimic the pine and spruce needles it spends most of its time on.

In both species, the female may lay up to 600 pearlescent green, oval eggs, depositing them singly on long, thin, silklike stalks secreted from glands near the tip of her abdomen. In just a few days, active, voracious larvae hatch from these eggs to consume soft-bodied, slow-moving prey such as aphids, scales, mealybugs, and whiteflies; older larvae may even attack the egg masses and young caterpillars of moths. The larvae, often known as aphid lions, literally liquefy the internal organs of their victims with digestive enzymes regurgitated through their needle-sharp, hollow jaws; then they imbibe the nutritious slurry through the same channels. After molting twice, the larvae spin spherical cocoons of silk and pupate, emerging ten or twelve days later as delicate, golden-eyed adults.

Active principally at night, the adults are capable of impressive aerobatics, particularly in the presence of echolocating bats, which they detect with special ears in their wings. *C. plorabunda* and *C. downesi* feed only on nectar and the sugary honeydew secretions of aphids and scales. Amino acids missing in their meatless diets are provided by yeast colonies living symbiotically in the walls of their digestive systems.

In the course of the breeding season, in June, *C. downesi* produces a single generation of offspring. These must pass the winter before mating the following summer. *C. plorabunda*, in contrast, breeds continuously, so that only the last generation overwinters. Despite *C. downesi*'s shorter breeding period and despite the tendency of the two species to occupy different habitats, I have often seen individuals of each only inches apart on the very same twig, during the month of June when both are sexually receptive; yet they do not interbreed. I do not think the slight color difference or seasonal asynchrony serves to prevent lacewings of one species from mating with individuals of the other. What does then?

The basics of courtship are the same for both *C. plorabunda* and *C. downesi* and are quite elaborate, involving sequential stages of attraction, vibrational singing, touching of mouthparts, fluttering of wings, and palpation of the genitals. The songs, however, are the most time-consuming and important aspect of courtship, and as I discovered, they differ radically in the two species.

Insects, like other animals, sing for many reasons but usually within the context of courtship and mating. Courtship is a kind of test that potential sexual partners administer to each other. The animal may ask, is my potential mate vigorous enough? rich enough (in resources important to reproduction)? sufficiently fecund? of the same species? Calls and songs can help individuals answer these questions by revealing the location, physical and reproductive condition, and species of suitors. And in some instances, songs may serve as a way for males to compete for the privilege of courting and mating with the available females. My recent work sug-

Songs, in the form of rhythmic abdominal vibrations, are the most important part of green lacewing courtship. Below: Male and female Chrysoperla plorabunda *touch mouthparts together while dueting. If the duet is satisfactory—that is, proves that both insects belong to the same species—the lacewings begin to copulate. Right: During copulation the male often turns around and away from the female. The pair may remain connected in this position for up to fifteen minutes.*

Both photographs by Raymond A. Mendez

gests that green lacewings use their songs principally for species discrimination; other sexual functions for calls are probably less important.

Chrysopids like *C. plorabunda* and *C. downesi* do not broadcast their songs through the air, as do more familiar acoustical insects. Early students of insect natural history noticed that lacewings occasionally vibrated their abdomens during courtship and mating, but no one equated this activity with the complex calling behavior of crickets or cicadas. In the late 1960s, while still an undergraduate in search of a research project, I was sent by my advisor, Frank M. Carpenter, to speak with his graduate student Lee A. Miller in the laboratory across the hall. There, Miller was studying the anatomy and physiology of the unique bat-detecting ear in the wings of green lacewings. With a healthy breeding colony of common North American *C. plorabunda* at hand and with Miller's extensive—and generously shared—knowledge of electronics and acoustics to help me, I chose to analyze abdominal vibration in courting lacewings. By getting the insects to walk on the underside of plastic wrap stretched over a paper cup, I could detect any of their movements or acoustical activities with a simple record player cartridge pressed against the plastic. The signals could then be displayed on an oscilloscope screen or recorded on audio tape. Preliminary results were intriguing, but only years later, when I returned to the project with more experience, did the remarkable features of the lacewing's unique and sophisticated communication system become clear.

Sexually receptive green lacewings pro-

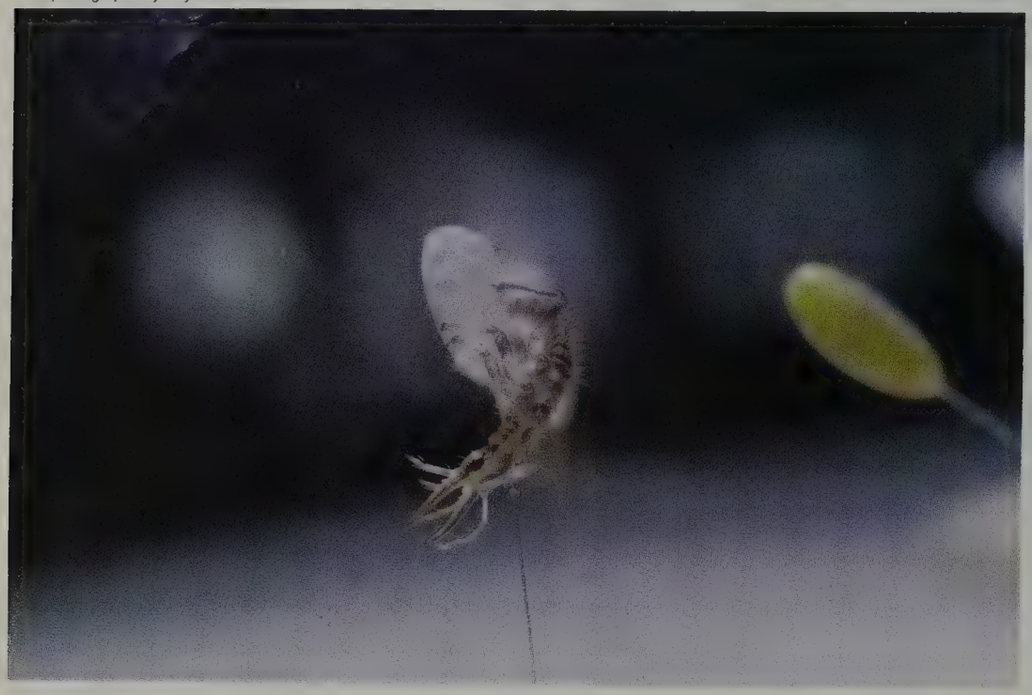
duce their songs by vigorously vibrating their abdomens up and down in a rhythmic, repetitive manner. No drumming is involved; that is, the abdomen never strikes the surface of the perch, but since the perch is usually lightweight—a blade of grass or a leaf, for example—it shakes in time with the vibrations, transmitting the signal for several inches. When another individual of the same species "hears" the signals, through receptors in its legs, it answers the singer with songs of the same type. In this way the two insects establish a duet that continues without pause while they gradually move closer toward each other. If each deems the other acceptable, the two touch mouthparts and, still dueting, swing their bodies into parallel position and copulate. Failure by either partner, at any time, to maintain the duet or to produce a correctly structured song will interrupt courtship and prevent copulation. An insect frustrated in this way while dueting may even lunge forward and bite the misbehaving individual. So similar are the calls of the two sexes that males often duet with other males and females with females for quite some time, occasionally attempting copulation, before realizing their mistake.

Green lacewing songs typically consist of discrete volleys of abdominal vibration. These volleys differ in characteristic, species-specific ways. Among the species I studied, for example, the frequency (number of vibrations per second) ranges from about fifteen to one hundred. (For comparison, the strings for middle C on a piano oscillate 261.6 times per second.) In some species, the frequency may rise or fall sharply during the course of a single volley, from one hundred to forty in *C. plorabunda,* for example. Volleys also have a characteristic duration and rate of repetition. (To get comparable results, all song analyses must be performed at some standard temperature since volleys are shorter, higher, and repeated more often as temperature rises.)

The songs of some species, such as *C. plorabunda*, are made up of a string of repeated, identical volleys. In these species, courting lacewings dovetail their calls, so that each volley of one insect is

Female green lacewings secrete thin, stiff stalks, which may hang down from a leaf or, as below, stand erect. The greenish eggs are laid at the tip of the stalk. After just a few days, a brownish larva emerges headfirst from the egg and crawls along the stalk to the leaf. Voracious eaters, Chrysoperla plorabunda *and* C. downesi *larvae attack slow-moving prey, such as these aphids, right, piercing them with sharp, hollow jaws. After liquefying their victims with enzymes passed down through their jaws, they suck up their meal through the same pathway. Upon reaching adulthood, these lacewings will subsist on a more delicate diet of nectar and honeydew.*

Both photographs by Raymond A. Mendez



answered by a volley from the other. Other species, like *C. plorabunda*'s close relative *C. downesi*, have more complicated calls consisting of several different volley types, repeated at different rates. An individual of this species completes a much longer sequence of several volleys, often lasting many seconds, before its partner answers in kind.

My studies convinced me that call characteristics most reliably separate closely related species of lacewings. The lacewings think so, too: in laboratory tests, *C. plorabunda* and *C. downesi* interbreed with each other, producing healthy hybrid offspring if they are given no other choice; but if they are allowed to establish duets with members of their own species, they will never make such mistakes. My work also persuaded me that since the insects look so much alike, the world probably contains more species of green lacewings than has traditionally been thought. This possibility has more than academic significance. For years, green lacewings have been used to help control the insect pests of important crop plants. Agriculturalists could be raising and releasing on their crops several different kinds of lacewings, while mistakenly thinking that only one species is involved. Unforeseen competitive or antagonistic interactions between incorrectly identified lacewings might drive most of the individuals from the target areas or prevent them from feeding on the pest organisms. In addition, the inadvertent introduction of lacewing species from distant geographical regions would almost certainly upset the natural balance of native ecosystems.

The best documented case of such mistaken identity involves *C. plorabunda*. Until very recently, this transcontinental North American species was considered part of *C. carnea*, an Old World species. Four years ago, however, my routine examination of the courtship activities of Swiss *C. carnea* revealed that its singing behavior differs radically from that of its supposed conspecifics on this side of the Atlantic Ocean. Individuals from North America promptly answer each volley during a duet, but Swiss *C. carnea* lacewings deliver a sequence of several volleys before expecting answers from their sexual partners. Also, each Swiss volley is significantly longer than its American counterpart and has a slightly rising frequency, whereas in most of the so-called North American *C. carnea*, the frequency drops sharply. Furthermore, the Swiss and American lacewings rarely interbreed, even when forced to keep company in the laboratory; the few matings that do occur produce very small numbers of mostly infertile offspring. What was long considered one species is, thus, at least two distinct species, physically identical to one another down to the most minute details of the male and female genitalia.

The case of *C. carnea* versus *C. plorabunda* confirms the existence of a hidden diversity of species in these insects; however, the situation is actually even more complicated. Several other, perhaps many, reproductively isolated, but physically indistinguishable, species can be acoustically recognized within each of the two taxa. At low altitudes in much of North America, *C. plorabunda* lacewings sing the same song, but at high altitudes in

the mountains of the western part of the continent, lacewings presumed to belong to the same species sing variations on the theme. The songs of these lacewings, which have their own geographical ranges of hundreds or even thousands of square miles, show some of the same features as lowland *C. plorabunda*, but they also differ in consistent, important ways. In the laboratory, these insects choose to mate with their own kind and, if given a choice, refuse to accept lowland *C. plorabunda*s as mates. Most likely, these lacewings, commonly referred to as song morphs, are actually separate species, even though they are reproductively compatible in every way except their songs.

So far, I have detected two such song-defined species in the mountains of California. These two species occasionally live so close together that both can be collected from the same branch. One is found along the entire spine of the Sierras, from Oregon to the San Bernardino Mountains outside Los Angeles, while the other frequents similar montane habitats over a more restricted range from central California to Arizona. Neither can be separated from the other, or from lowland *C. plorabunda*, without close scrutiny of calling behavior.

An analogous situation exists in Europe. There, *C. carnea* breaks up into several distinctive song morphs at high altitudes in the Swiss Alps, while consistently maintaining a uniform song type at lower altitudes over huge areas of Europe, western Asia, and northern Africa. As with *C. plorabunda*, several of these otherwise indistinguishable morphs can coexist at certain sites without losing their acoustical identities. Thus each is probably a valid species whose members mate only among themselves.

Swarms of such sibling species have almost certainly arisen within the genus *Chrysoperla* all over the world. The process of species formation has probably been a relatively recent one since all the species and morphs look so much alike and since they are still genetically close enough to hybridize if forced to. How might the singing behavior of green lacewings be encouraging the proliferation of new species?

Imagine that a chance mutation in, say, *C. plorabunda* produced one individual with an altered song. Most of the time, the odd singer—unable to duet properly—would simply be rejected by every potential mate in the population. The mutant could successfully reproduce, however, if he or she found a "captive audience"—a sexually receptive insect isolated from the rest of the population. This kind of situation is perhaps most apt to arise among small populations in mountainous areas, where population densities are low and individuals have trouble dispersing very far. Since calling patterns are inherited, at least a few of the offspring of such a mating would exhibit the mutant calls themselves. If like chose like for generations thereafter, two distinct, reproductively isolated populations would emerge. Thus speciation could be catalyzed by song divergence alone.

Most speciation is thought to occur allopatrically, that is, when one part of an existing population is separated from the main body by some physical barrier, such as a mountain range, river, or ecologically inhospitable zone. The two isolated parts of the species then evolve independently for many generations. If they reestablish contact at some later date, they cannot or will not interbreed because of genetic and behavioral changes that developed during their long period of separation and that

Below: In some species of green lacewings, the adults are carnivorous, feeding on aphids and other small, nonflying insects they find crawling around or sitting on leaves and other parts of plants. Right: Chrysoperla carnea *is a common European green lacewing; the strikingly similar North American* C. plorabunda *was only recently recognized as a separate species. The world probably has many such "hidden" species.*

C.W. Perkins; Animals, Animals

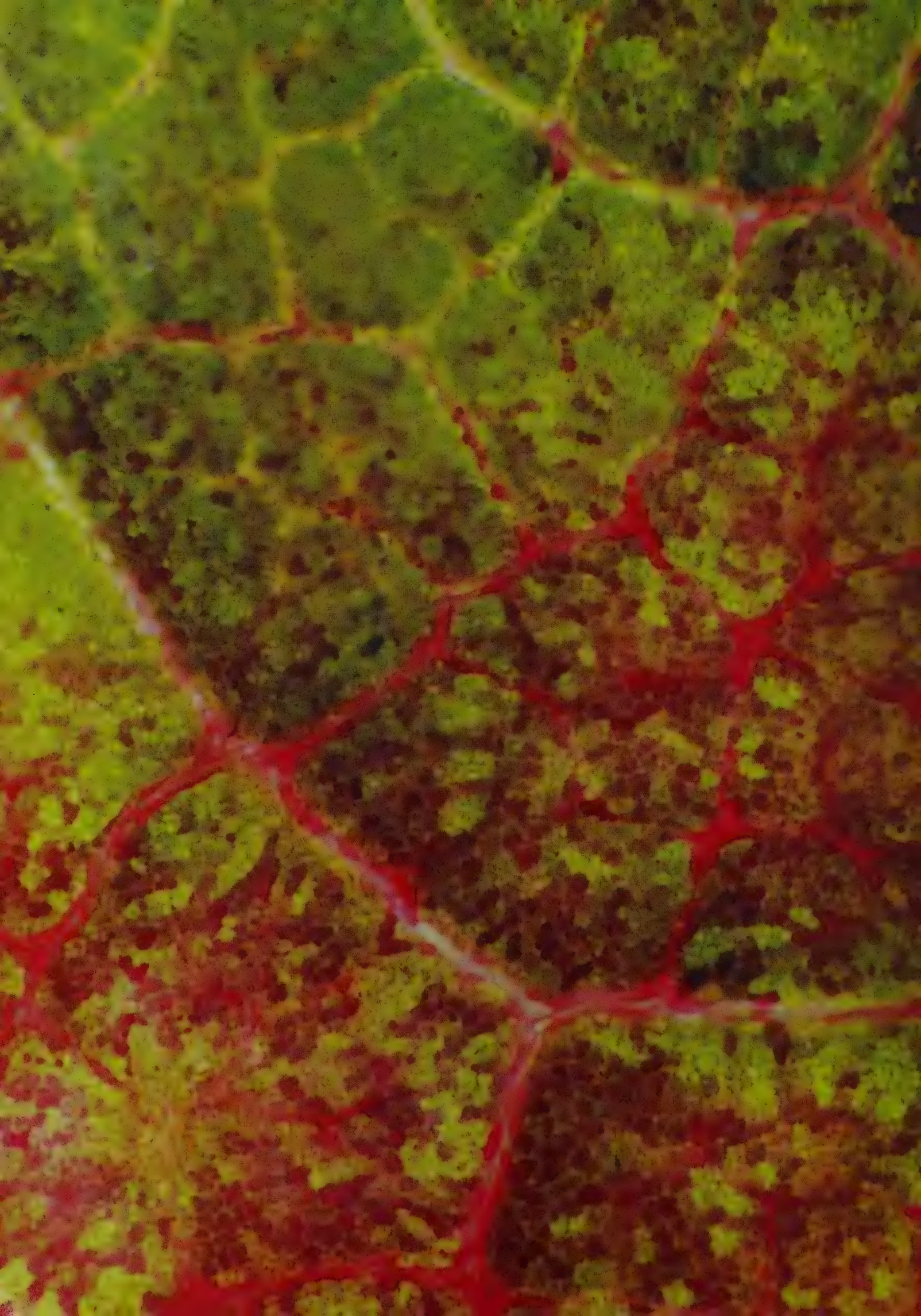
have rendered them reproductively incompatible.

Rarely, however, reproductive isolation—and hence speciation—develops between two parts of a population in the same location without the aid of any physical barrier. This kind of speciation—known as sympatric speciation—is extremely rapid, often following a mutation large enough to abruptly separate the mutant from the rest of the population; no lengthy physical separation is required.

Speciation can never be observed directly, so proving beyond a doubt which type—allopatric or sympatric—is involved in any particular case is nearly impossible. It is especially difficult to prove how rapidly differentiation may have occurred. I am convinced, however, that the many species of green lacewings, strikingly similar in almost every way except their songs, should be added to the list of those that may have evolved via sympatric speciation.

Much work remains to be done on the genetics of green lacewings, but my first rough approximations, using straightforward Mendelian analysis, suggest to me that it is at least possible that lacewing singing behavior is under the control of relatively few genes—perhaps as few as two or three. If this turns out to be the case, then the mutation of a single gene might well be enough to produce major alterations in the courtship call. The result could be, assuming the mutant succeeds in finding a mate, nearly instantaneous speciation affecting only courtship and mate choice. Very likely, the species produced by this sort of process would be extraordinarily similar in every other physical, physiological, and genetic respect; they would also be interfertile. In addition, because the arbitrary, random changes leading to this speciation would involve no adaptive responses to different environmental conditions, the new species would almost certainly share identical ecological niches. The green lacewings appear to satisfy all these conditions.

To my mind, sympatric speciation among green lacewings seems likely. However, the verdict is not yet in, and no final proof—one way or the other—may ever be established. Whatever further work shows, one thing is clear: the course of basic research can be delightfully tortuous. What began for me as a well-defined, descriptive study of courtship and mating in a common lacewing gradually shifted, leading me to ask fundamental questions about natural biological diversity and the origin of species—still one of life's most profound mysteries. □



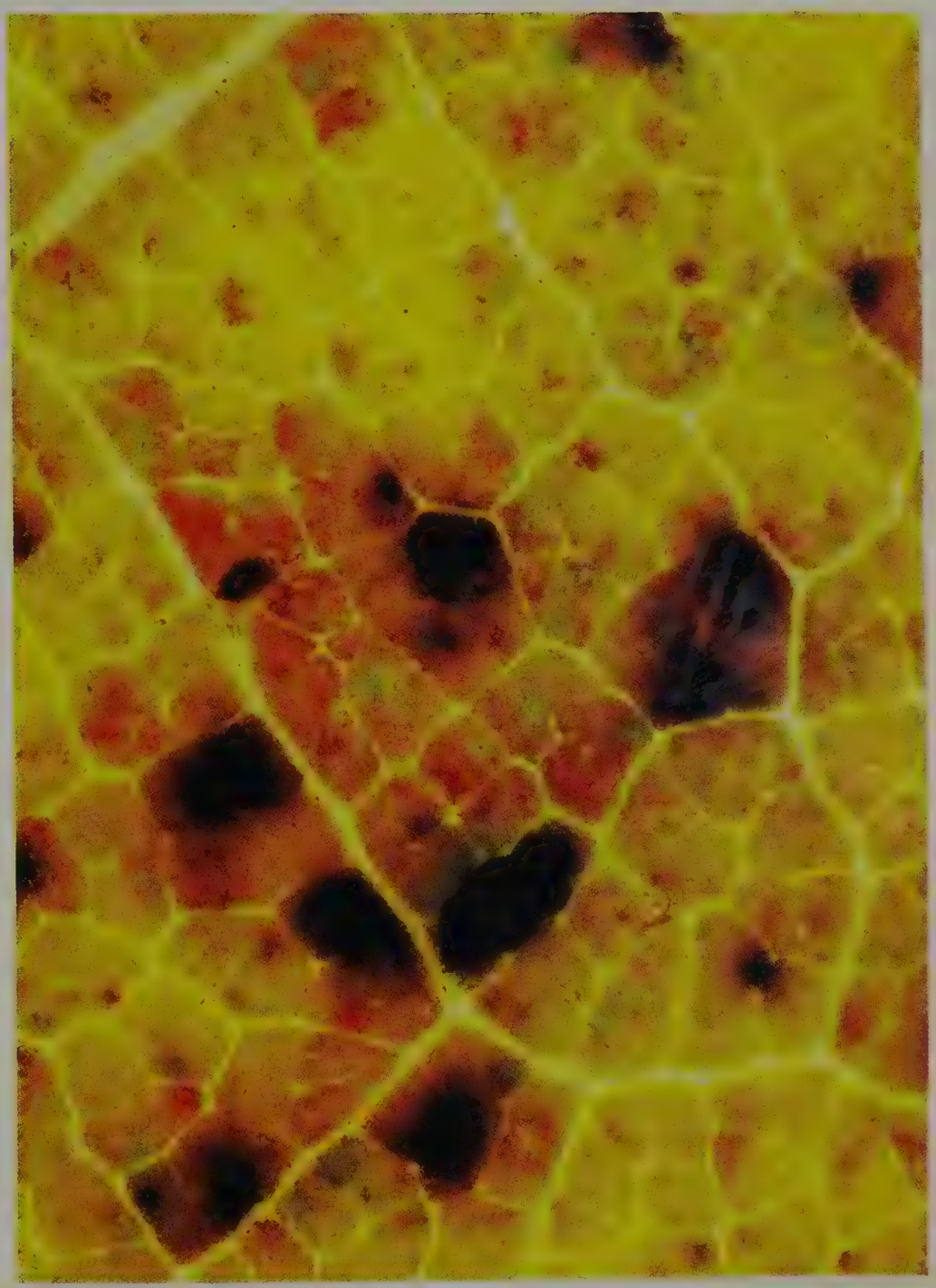
A Harvest of Decay

Text by E. O. Wilson • Photographs by Thomas Eisner

Like astronauts in soft landers, we are descending in these photographs toward the surface of fallen leaves, and already we can see them in a very different way. The green of the chlorophyll has faded to unmask the blues, reds, and yellows of the anthocyanins and carotenoids, creating combinations that vary from one species to another. The cell walls divide the surface into local fields of chloroplasts, among which veins meander and split to create repetitive, fractal designs. The complex production and delivery system is no longer functional. But the leaves have been invaded by millions of bacteria and fungi, and these microscopic organisms proliferate into new patterns as rich as the ones on which they feed. Life has come back, as in Thomas Kinsella's "The Monk,"

Savouring in death a tide of light,
Harvest in all decay,
Spring in February night.

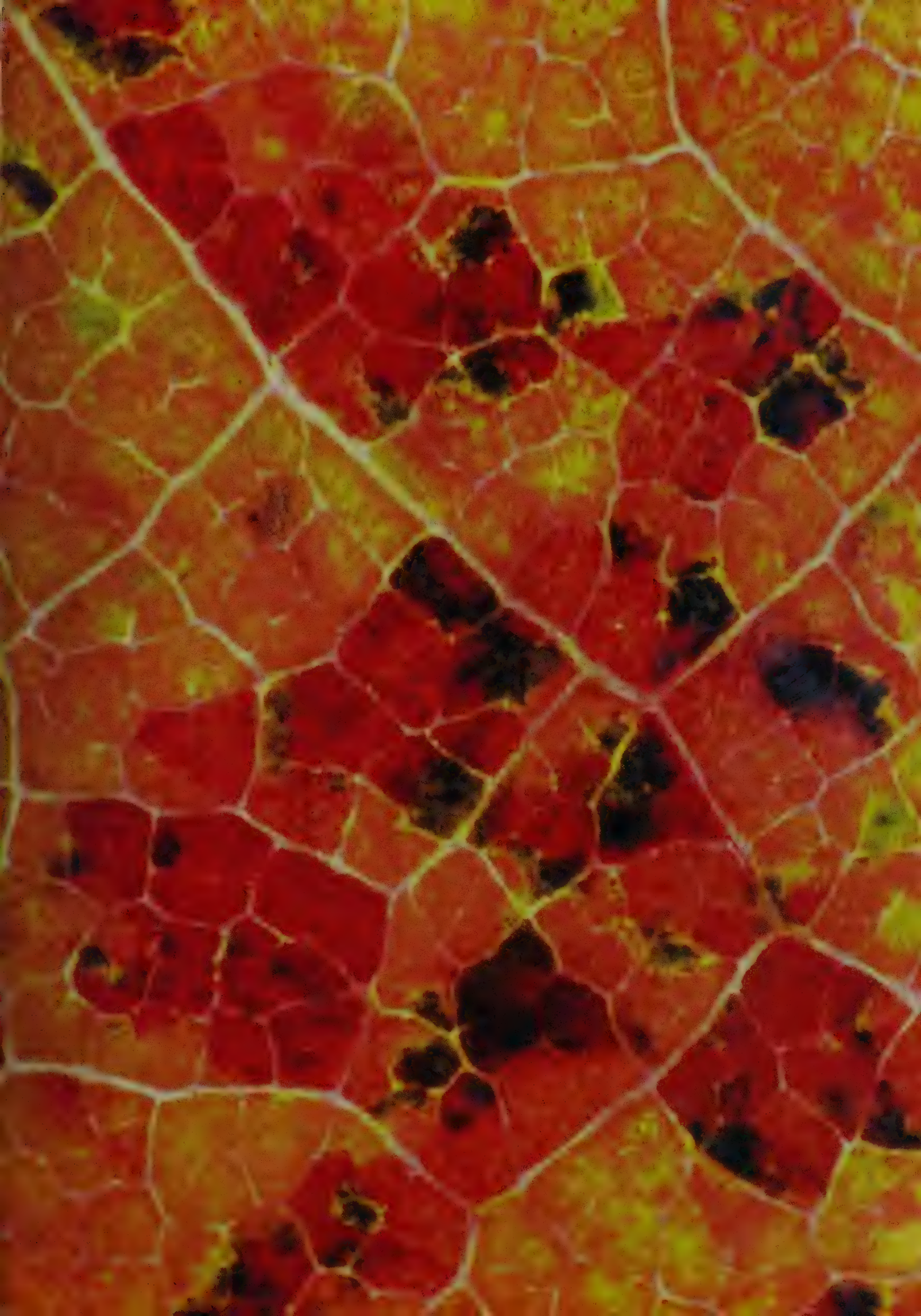
Such leaf surfaces often bring to mind works of abstract art, grilles, and ideograms. But what is the relation of such living structure, or at least our perception of it, to real art? Although naturalists who focus on the leaves register the beauty of the skeletal design, their excitement is not limited to these abstract features. They know that entire worlds exist just beyond the resolution of the photographs. The droplets of water within the deteriorating mesophyll are miniature seas for the bacteria and protozoans. The fungal mycelia expand like forests and provide food for roundworms and insects grazing across the surface litter. Each of the organisms has a genetic code of a million or more nucleotide pairs, and it represents just one of the endlessly splitting lineages



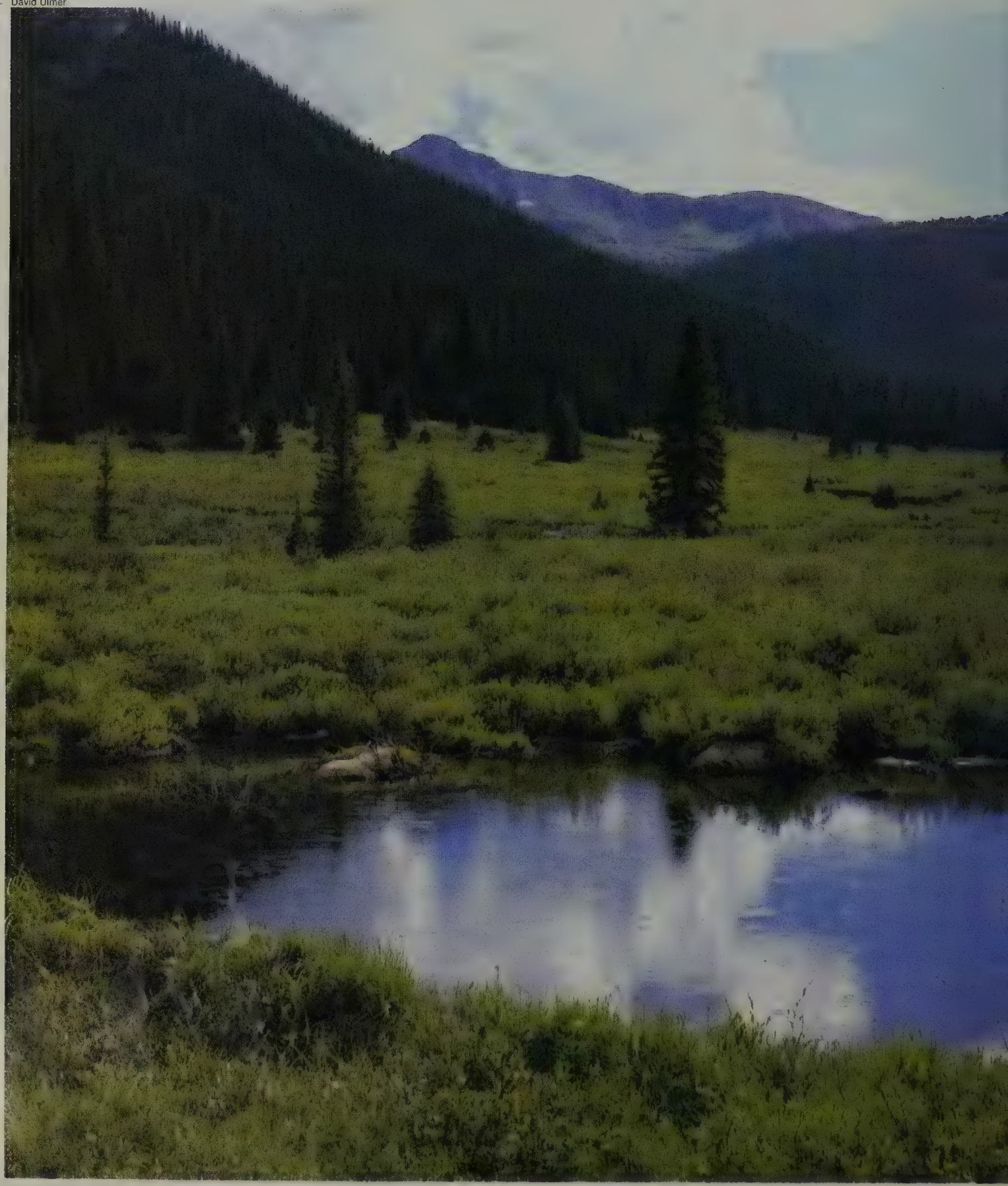
that date back into geological time. Only an infinitesimal part of this universe has been explored. And the more we learn, the more questions we are able to ask. Life presents us, as Camus said, with an implacable grandeur.

In contrast, to magnify a painting in similar fashion is quickly to leave life behind and to enter a world of dry pigment, offering no mystery at all. The design in an artifact has meaning only at the macroscopic level. It serves to transfer feeling from artist to observer, often through a single stroke of sensation. An important work of art deepens in content only to the extent that the observer considers its history and symbolism—qualities that are largely external to the work itself.

Does this divergence mean that art and natural history belong to two realms of experience, so that apparent similarities are illusory? Not if we realize that the human brain itself is a product of organic evolution, and that our aesthetic feelings are themselves part of nature. People perceive the world with each of the senses in only a limited number of ways out of the vast array that can be imagined and that have, in fact, evolved in the animal kingdom. We also innately prefer certain geometric patterns and ways of forming words about color. Our equally deep urge to explore and control the environment brings us to hidden places, including the topographies of decaying leaves. These properties of human nature have almost certainly enhanced survival in times past. Evolution by natural selection created the processes of the mind, and a fuller understanding of its principles might someday bring about a close conjunction of art and natural history. □



David Ulmer



Taylor River, Colorado

by Robert H. Mohlenbrock

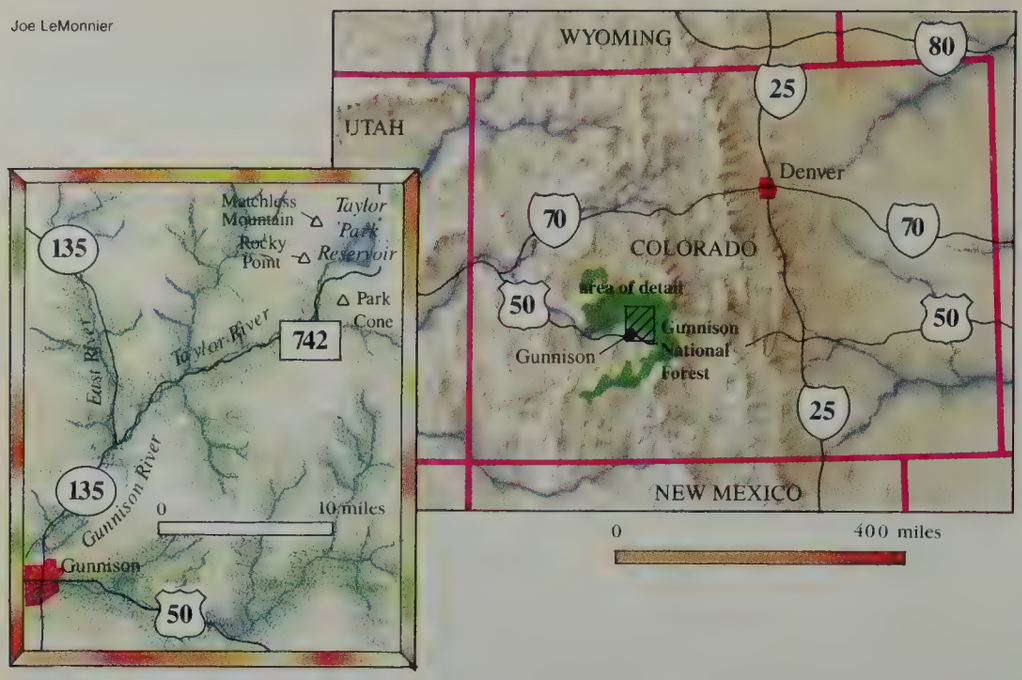
In 1853, Capt. John Gunnison led a party of topographical engineers through western Colorado, across the main range of the Rocky Mountains, seeking a middle route for a railroad from the Mississippi to the Pacific. The mountains proved too high for a feasible railroad route, but the discovery of gold in 1878 opened up the territory. Although Gunnison was killed by Indians, his name lives on in various landmarks, including Colorado's Gunnison National Forest.

Visitors to the area today can follow an all-season forest road to Taylor Park Reservoir, a huge and popular recreation lake. The road goes past the winter range of a herd of Rocky Mountain bighorn sheep and near their summer range on three mountain peaks. While the sheep are elusive, they can sometimes be seen grazing during the winter months or during their spring and fall migrations.

Warren Martin Hern

Left: A beaver pond near the headwaters of Taylor River. Above: Female Rocky Mountain bighorn sheep are part of Gunnison National Forest's threatened herd.

Joe LeMonnier



Taylor River

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Gunnison National Forest
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(303) 874-7691

Rocky Mountain bighorn sheep are sturdy-bodied mammals that graze in mostly open areas of high mountain regions. Adult males, whose creamy white rump patches contrast with their generally gray-and-brown coats, weigh as much as 330 pounds. Their large brown horns curl upward and backward, then down and forward. The horns are not shed but grow throughout the sheep's life, continuing to curl and forming annual ridges. The approximate age of a bighorn sheep can be estimated by counting the ridges. Females are much smaller, lack the contrasting hair color, and have smaller, scarcely curved horns.

In winter, a herd of almost one hundred animals congregates in a steep, rocky canyon near the junction of the East and Taylor rivers, where the elevation ranges between 8,000 and 9,000 feet. Breeding occurs here in November and December. During the winter months, the sheep graze primarily on a variety of grasses, although they occasionally nibble on sagebrush, rosebushes, serviceberries, aspens, and willows. The sheep are agile climbers and can move over the rocky terrain with amazing ease. They usually feed during the day, occasionally taking a noontime nap. At night, they seek protection among the rocks.

In late May, when snow begins to melt on the high mountains northeast of their wintering grounds, the bighorn sheep set out on a fourteen-mile trek along Taylor River to a few mountain peaks west of Taylor Park Reservoir. Serving as the lookout, the dominant ewe cautiously leads the way. When there is trouble, she alerts the rest of the herd and quickly leads them to safety.

The lambs are born on the way to the summer grounds on the top of Matchless Mountain, whose 12,383-foot summit is well above timberline. Here the ewes and newborn lambs spend the summer, foraging on the vegetation until the first heavy snows blanket the mountain top. The rams, meanwhile, go to two slightly lower mountain peaks nearby—Rocky Point and Park Cone. Early snows on the mountains may force the sheep to start down to their wintering site earlier than usual, but the winter migration normally begins in October.

This seasonal migration took place routinely for years, but early in the 1980s, wildlife biologists observed that the sheep were spending more time than usual on the wintering grounds and were using different migration routes to the summer range. In fact, some didn't go to the summer range at all. Concerned that the herd might not maintain itself, range consultant Jim Berry, assisted by zoologist Tom Hobbs, of the University of Colorado, and wildlife manager Tom Henry studied the Taylor River herd in 1982.

They discovered that lungworm was becoming prevalent among the animals because they were remaining at lower altitudes, where, with the coming of warme weather, they were exposed to the sna that transmits the parasite. The sheep in advertently eat the snails that contain th lungworm larvae, and the larvae develo into adult worms in the sheeps' lung causing a pneumonialike disease. In add tion, the grasses on which the herd de pended were diminishing because of th greater grazing pressure. To create mor grassland in the winter range, the Fores Service burned acres of sagebrush i 1982, 1983, and 1984, encouraging th regrowth of forage grasses such as brom and fescue. They also tried salting th summer range area in an effort to entic the animals to migrate to the mountai summits—but without success.

Finally, the study team concluded tha the reason the sheep were delaying, alte ing, or skipping their normal migration t

A Forest Service employee uses a drip torch to create a firebreak around an area of forest land scheduled for burning.

ne summer range was because they had ost eye contact with landmarks along neir migration route. Through the years, ntervening forests of lodgepole pine had rown up, in effect preventing the sheep rom seeing where they were going. Instead, they would often wander along Taylor River, where nine campgrounds and he associated human activity often discouraged their progress. Only those sheep hat left their wintering ground earlier in he spring than usual, while snow still covred the ground, could avoid this human ontact.

Jim Paxon, the Taylor River district anger of the Gunnison National Forest, ame to the conclusion that if the Taylor River herd was to be saved, the sheep vould have to take priority over timber. The decision was made to remove the interfering trees that had grown up in the steep-sided ravines of the winter range. Most of the lodgepole pines were not desirable timber in any case, since they were heavily infested by western mistletoe. The mistletoe had weakened the wood fibers of the pines and distorted their limbs and branches.

The doomed trees, however, were growing on such steep slopes that normal timber-cutting methods could not be used. Early in 1985, the Forest Service made the startling announcement that 1,000 acres of forest would be burned. In May and June, foresters carrying drip torches burned 600 acres of lodgepole pine. The remaining 400 acres, consisting of nearly inaccessible terrain, were burned by "helitorch": a fifty-five-gallon drum of gasoline jelly, suspended fifteen feet below a helicopter. Golf-ball-sized globs of the jelly, ignited by a spark plug as they flow out of the drum, splash into flames when they hit the ground.

In evaluating the 1985 helitorching, Jim Paxon estimated there was a 70 percent kill of the standing timber, opening up the area and returning it to grassland. Most of the sheep immediately began to use their usual summer migration route. Lodgepole pines, however, have cones that open and shed their seeds only after fire. Since the 1985 burn, seedlings have sprung up everywhere. Paxon says that the Forest Service will reburn every seven years in order to keep the lodgepole pine under control.

"This Land" highlights the biological phenomena of the 153 U.S. national forests. Robert H. Mohlenbrock is distinguished professor of botany at Southern Illinois University at Carbondale.

Paul M. Pennington

Gaps in the Asteroid Belt

Why asteroids are absent where they should be present has now been explained

by Stephen P. Maran

Asteroids are small rocky objects found mostly in the "asteroid belt," a region in space between the orbits of Mars and Jupiter. In this locality, where astronomers had once searched for a planet, the asteroids move through slightly elliptical orbits around the sun. Several thousand asteroids have been tracked and cataloged since the first of them, Ceres, was discovered in 1801. The largest of the known asteroids, Ceres is about 637 miles in diameter. Many thousands of smaller ones not yet identified are believed to exist.

A curious aspect of the asteroid belt is the existence of gaps where many asteroids might be expected to be found but within which few have been. One such gap may be related to an equally curious property of meteorites (chunks of stone and iron that fall on the earth from space); namely, twice as many of the most common type of stone meteorites fall in the afternoon as in the morning.

Six of the gaps in the asteroid belt are now called Kirkwood gaps for the nineteenth-century American mathematician Daniel Kirkwood who discovered them and announced his findings in 1867. Kirkwood arranged the ninety-one then-known asteroids (sometimes called minor planets) in the form of a two-page table, listing them in the order of the lengths of the semimajor axes of their orbits around the sun. (The long axis of an elliptical orbit is called the major axis and one-half of its length is the "semimajor axis," a standard parameter of orbital research.)

Once the asteroids were tabulated in terms of their semimajor axes, rather than in the order in which they had been discovered (the conventional way), the existence of six gaps became apparent. Kirkwood was quick to note that each of these gaps was at a location in the asteroid belt where "the periods of asteroids [if there had been any there] would be commensurable with that of Jupiter." That is, a small multiple of the period of such a hypothetical asteroid (the amount of time required for one revolution around the sun) would be equal to one period of Jupiter or a multiple of Jupiter's period. For example, an asteroid makes three turns around the sun, while Jupiter makes one, or an asteroid makes five turns, while Jupiter makes two.

Like Kirkwood, others have since speculated that the existence of the gaps was related to the "commensurability" of the orbital period of asteroids previously in the gaps with the orbital period of Jupiter. A modern version of the commensurability explanation would run as follows: Jupiter and a gap asteroid would be lined up with each other at the same points in their orbits in a regularly repeating manner. The disturbance of an asteroid by the gravitational pull of Jupiter on, say, every second or third orbit would thus send the asteroid swinging into either a larger or a smaller orbit. The gaps would therefore have been produced as asteroids that were originally present in the asteroid belt were sent into other orbits.

Would the effect of commensurability take place as stated and is it, in fact, sufficient to remove all or nearly all asteroids from the gaps?

Investigators of the Kirkwood gaps have tried to test various theories of gap formation by conducting numerical experiments with electronic computers. In such an experiment, hypothetical asteroids, in specified orbits in a Kirkwood gap, are studied as they would revolve around the sun over periods of many years, subject to the gravitational influences of Jupiter and other planets. The objective is to determine whether the asteroids would move into orbits that would take them *out* of the gaps. The drawback to this approach is that it requires a great deal of computer time to trace the motions of an asteroid over, say, ten thousand years. And computer time is very expensive.

In 1982, Jack Wisdom, a mathematician now at the Massachusetts Institute of Technology, devised a new computer technique for approximating the motion of an asteroid. His method enabled him to trace asteroidal motion over a given period of time about a thousand times faster than previous techniques allowed. Thus, in a reasonable amount of computer time Wisdom was able to follow the motions of hypothetical gap asteroids over hundreds of thousands and even millions of years. Previous investigators were unable to confirm any Kirkwood gap theories through numerical experiments that simulated orbital behavior over tens of thousands of years. With his calculations, Wisdom discovered that an asteroid initially located in a Kirkwood gap orbit, and which moved only into modestly different orbits over tens and hundreds of thousands of years, might suddenly, after a million years, be propelled into a radically different orbit, one far more cigar shaped than the nearly circular ellipse of its initial orbit. This type of unexpected change in orbital behavior is known as chaotic, a term that refers to motions that can be described by equations but are nevertheless very surprising.

The cigar-shaped orbit that Wisdom computed for asteroids that begin by making three turns around the sun, while Jupiter makes one, took the asteroids far inside the asteroid belt, so that they crossed the orbit of Mars. This at once suggested an explanation for at least that particular Kirkwood gap, namely, that asteroids that begin in nearly circular orbits at distances of about 2.50 astronomical units (A.U.) from the sun (1 A.U. equals 93,000,000 miles) will, after periods of millions of years, be thrown into orbits that cross that of Mars. Then the gravitational influence of Mars can readily pull them into still

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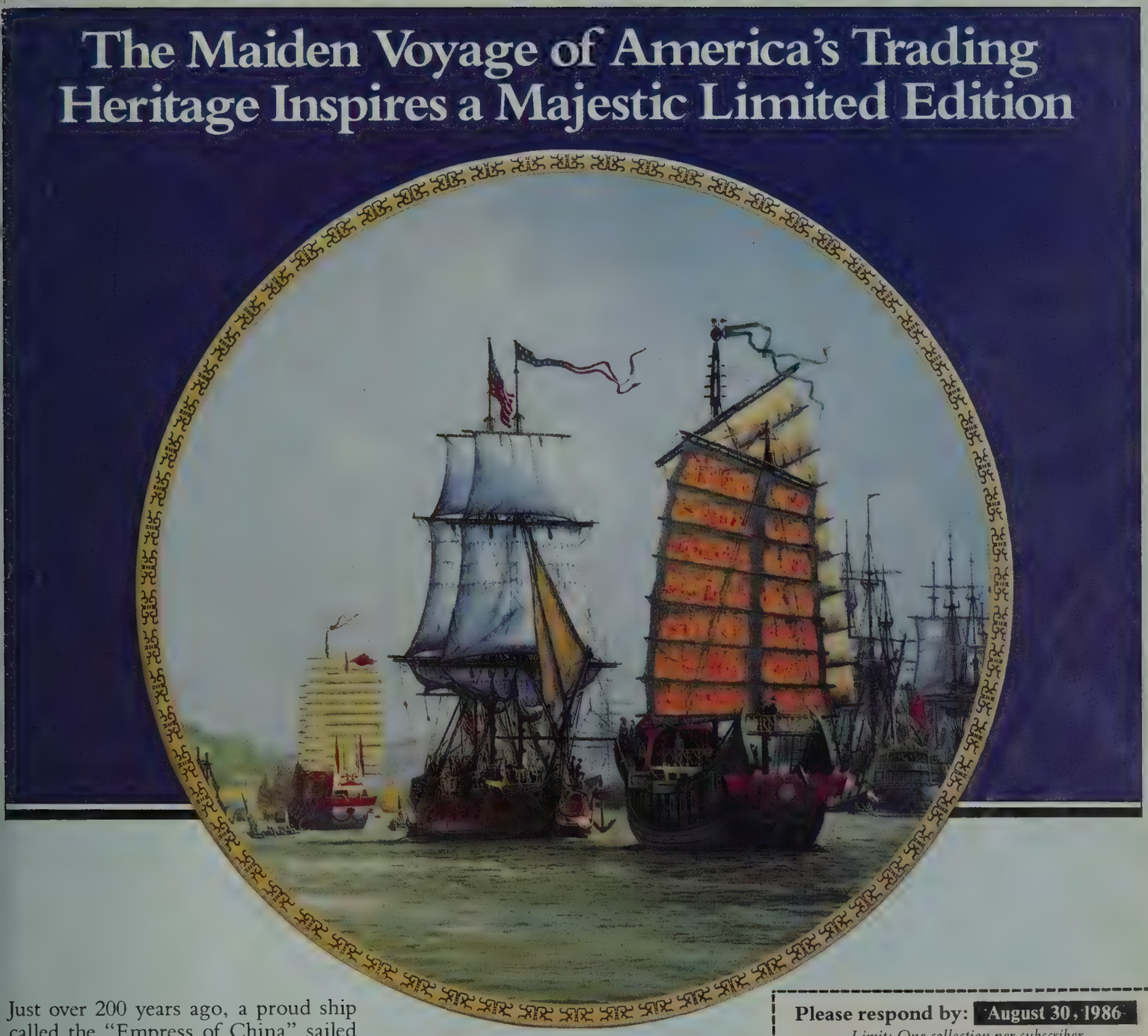

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other orbits (and sometimes into colliding with the planet), so that asteroids are removed from a region in the asteroid belt that is located 2.50 A.U. from the sun, and that region thus becomes a gap.

At first, Wisdom's work met with skepticism because other experts were not familiar with his mathematical innovation and rightly proclaimed that it represented a shortcut of unknown reliability. Subsequently, however, Wisdom duplicated some of his key results by standard methods using no shortcuts. He even formulated an analytical theory, based on principles rather than on numerical examples that appears to support the validity of his findings.

In the meantime, George Wetherill, a veteran investigator of asteroid and comet orbits at the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, in Washington, D.C., was trying to establish the region in space from which meteorites come. In this work, on which he had concentrated for many years, he had come to pay special attention to the commonplace observation that twice as many of the most common type of meteorites seem to fall on the earth in the afternoon as in the morning. These are stone meteorites, called ordinary chondrites after their round mineral inclusions or chondrules. This strange phenomenon was long explained by the assumption that more people are outdoors and alert in the afternoon than in the morning, so more meteorites are seen in the afternoon. Wetherill, however, found that most meteorite falls are reported by farmers at work in their fields, and they, of course, start work early in the morning. He concluded that more stone meteorites really do fall to Earth in the afternoon. The only logical explanation would then be that these meteorites, when still orbiting in space, follow orbits that cause them to intersect the afternoon hemisphere of the earth. The conclusion was supported by the meager evidence available on the orbits of ordinary chondrites that were seen to fall—just thirty fairly well determined incoming orbits.

The ejection of asteroids from the Kirkwood gap, located at 2.50 A.U. from the sun, into cigar-shaped orbits that cross the orbit of Mars has come to be known as the Wisdom process. In 1984, Wetherill suggested that the Wisdom process might be capable of throwing the asteroids out of that gap into even more elongated orbits. These orbits would have their points of closest approach to the sun located near the orbit of the earth. Wetherill further proposed that fragments produced by collisions of asteroids within the belt might

kewise be thrown out of the gap at 2.50 .U. into similar cigar-shaped orbits.

If these two conjectures could be veri-ed, then a basic problem of meteorite udy would be solved. Specifically, teroidal fragments in the orbits pro-osed by Wetherill would fall on the earth reponderantly in the afternoon, as is ob-rved for the common type of meteorites, ecause their cigar-shaped orbits would tersect the afternoon hemisphere of the rth. These ordinary chondrites that fall the earth would then be identified as agments of asteroids from the Kirkwood p at 2.50 A.U.

Wisdom took up the challenge of trying prove Wetherill's hypotheses. He made me very time-consuming calculations, ch corresponding to a different set of arting conditions. In his last calculation e found that a hypothetical object from e Kirkwood gap at 2.50 A.U. (in which asteroid makes three turns around the n, while Jupiter makes one) would in-eed enter the orbit prescribed by Weth-rill as necessary for an ordinary chondrite fall on the earth.

Elaborate calculations by Wetherill, hich take into account the breakup of eteorites in the earth's atmosphere and any other effects, appear to show that e Wisdom process can account for the irty known orbits of ordinary chondrites. hose calculations also confirm that the Visdom process, as already mentioned, an account for the tendency of ordinary hondrites to fall to Earth twice as often in e afternoon as in the morning. In addi-on, the Wisdom process can account for e estimated total mass of ordinary chon-rites that fall through the earth's atmo-phere each year. That total is about one undred tons of stone, but most of it is lost rough disintegration in the atmosphere r by landing in the sea.

The Kirkwood gaps now appear to be roduced by gravitational interactions of upiter and the asteroids in a manner so omplex that very advanced computing echniques are required to demonstrate em. Remarkably, Wetherill's calcula-ons show that most of the stone meteor-es that fall on the earth can be identified ith a particular region of origin in pace—specifically the Kirkwood gap at .50 A.U. from the sun—where orbiting steroids make three turns around the sun or each orbital revolution of the planet upiter.

Stephen P. Maran is a senior staff scien-ist in the Laboratory for Astronomy and Solar Physics at NASA's Goddard Space Flight Center in Greenbelt, Maryland. The opinions expressed here are his own.

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No August Doldrums

Thomas D. Nicholson

Three of this month's bright planets are evening stars (Venus, Mars, and Saturn), and two are morning stars (Mercury and Jupiter); their brightness and placement assure an excellent planet show virtually from dusk until dawn.

Mars is past its prime brightness, but the decrease in brilliance probably won't be noticeable yet. In compensation, Venus, Jupiter, and Saturn are even brighter than last month. The spacing of these planets in the sky hasn't changed significantly since July. Mars sets a little earlier in the morning and Saturn noticeably earlier in the evening, but Jupiter and Venus improve their positions for viewing.

The first bright object (other than the moon) you will see at night is Venus, coming out of the early twilight in the southwest. It is near maximum brilliancy now, and about as far left (east) of the sun as it will get; both its brightness and position favor visibility. Only its proximity to the horizon diminishes its splendor a bit. As soon as you see Venus, turn your back to it and look east, where the sky darkens earlier. There you should see Mars, reddish and well up in the southeast. As darkness deepens, Saturn will appear to the right of Mars, higher in the south. Jupiter will come up about an hour or so later, due east and brighter than Mars. Meantime the first-magnitude stars Antares, Spica, and Regulus (in that order from east to west) fill in between the planets. Venus is gone from view by about 9:00 P.M. The other planets slide west in progression, keeping apace with one another and with the stars. Saturn sets before midnight and Mars after that, but Jupiter hangs in there until dawn.

Events in the calendar below are give in local time unless otherwise indicated.

August 1: A slender, crescent moo decorates the dawn today and perhap again tomorrow, but after that, probabl not again until late in the month.

August 2: Mercury has completed th brief reversal of its stellar path (retrograd motion), which comes with inferior con junction. It gradually becomes more visi ble as a morning star as it moves eastwar once again.

August 5: New moon, at 1:36 P.M. EST, is in Cancer.

August 7: The end of Saturn's retro grade motion is a sign that we won't see i much longer as an evening star (only fo another two months).

August 9: You might have seen th young crescent moon (three days pas new) last night; you should see it easily i the southwest tonight.

August 10: Spica, in Virgo, is near th moon tonight.

August 11: Mercury is at greatest west erly elongation (maximum distance to th sun's right). It is bright and well placed a a morning star from about the 8th to th 18th. Look low in the east-northeast, to th left of the rising sun, during the early twilight.

August 12: Mars's retrograde motio has retraced its steps back int Sagittarius's "teapot," but the plane turns today into its proper easterly path taking it swiftly toward Capricornus First-quarter moon is at 9:21 P.M., EST, i Libra, a bit to the right of Saturn.

August 13–14: Tonight's moon passes below Saturn just before they set and the squeezes past Aldebaran (the reddish sta

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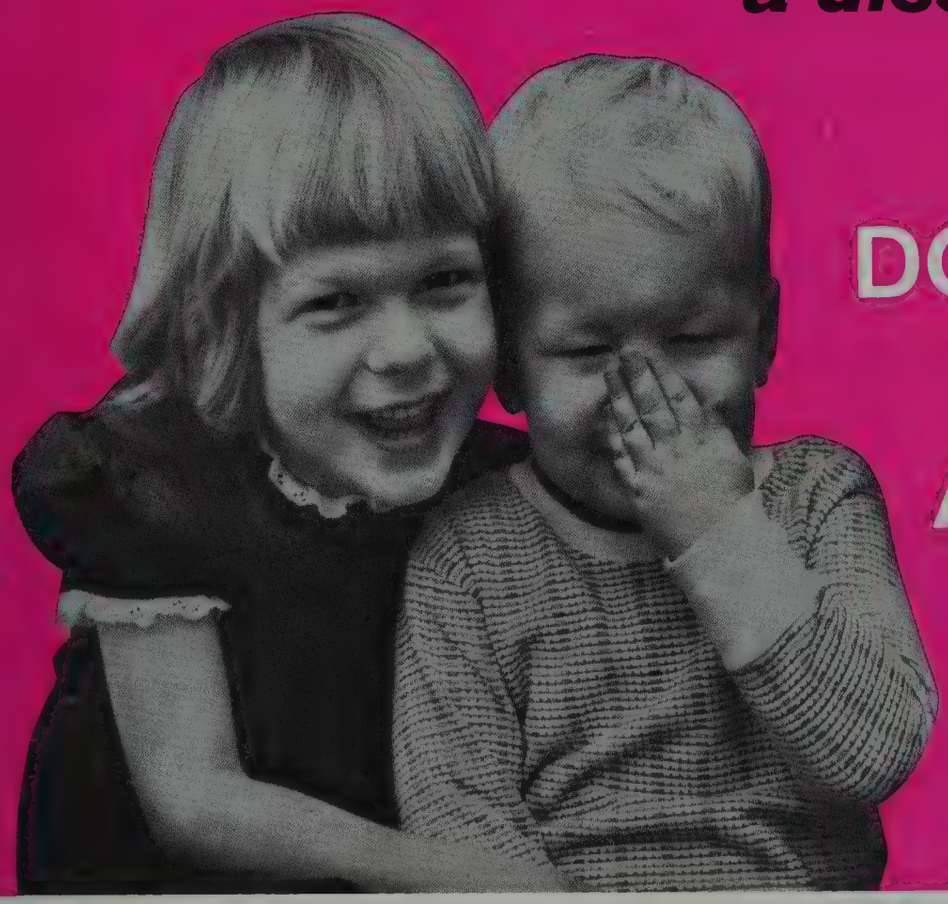

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under them) below the horizon. The moon covers the star (an occultation) over eastern Europe and Asia. On the 14th, the moon is to the left (east) of Saturn and Antares, in Ophiuchus.

August 15–16: The growing gibbous moon spends these nights in Sagittarius near Mars. During the day on the 16th, it occults the reddish planet over parts of Africa, South Asia, and Australia at about the time it reaches perigee (nearest the earth).

August 19: The moon is full at 1:54 P.M., EST. It will be in Aquarius as it rises tonight. The only objects visible near it through the scattered moonlight are Mars (above and to the right) and Jupiter (below).

August 20–21: The moon is near Jupiter on both nights. It slips past the planet during daytime on the 21st and is closer to the planet that night.

August 21–23: The moon drifts east through the dim stars of Pisces as it wanes and briefly slips over into Cetus, close to Pisces's southern border. The Whale's bright star (below the moon) is Diphda.

August 26–27: When the moon rises after 10:00 P.M. tonight, it is in Taurus. The closely packed little group of stars known as the Pleiades (also called the Seven Sisters) is close by to the right. Last-quarter moon occurs at 3:30 A.M., EST, on the 27th.

August 27: Venus is at greatest easterly elongation (greatest distance to the sun's left). This ordinarily improves the planet's appearance as an evening star, although at this time of year it is too far south to be at its best. Its brightness (still increasing) more than makes up for this deficiency however. From now until late Septembe would be a good time to try finding it i daylight with the aid of binoculars. Searc well to the left of the sun in the afternoon

August 28: This morning's moon is sti in Taurus, above the V-shaped Hyades which makes up the Bull's face. Apoge moon (farthest from the earth) is at 10:0 A.M., EST.

August 31: You can see the twin stars o Gemini, Pollux (the brighter) and Casto near the crescent moon in the mornin sky. In the evening, Venus will be excep tionally close to Spica, the brightest star i Virgo.

Editors Note: The Sky Map in the Jul issue shows the evening constellations an stars and gives the times for use.

Helmut Wimm

Seven planets and the moon are above the horizon in the early evenings of late August. Their positions in the sky are shown for an observer looking south about two hours after sunset on August 18. Except for the position of the moon, the scene will remain almost the same for most of the month. Before the 18th, the moon will be slimmer (earlier in phase) and to the right (west) of the position shown; on the 19th it will be full and closer to Jupiter; on the 21st it will be past Jupiter; and later in the month, it will be below the eastern horizon. The bright planets are shown as starlike images, from right to left: Venus, Saturn, Mars, and Jupiter. Uranus, Neptune, and Pluto are too dim to be seen without telescopic aid, but their positions are indicated by their initials (U, N, and P). Note that all the planets shown (except for Pluto) lie along an approximate line stretching from Venus in the west, low across the southern sky past the moon, to Jupiter in the east. Pluto (whose orbit is greatly inclined relative to those of the other planets) is the only maverick. The line traces out the southern (below the equatorial plane) branch of the ecliptic (the plane of the earth's orbit) and very nearly that of the other planets as well—with the exception of Pluto and Mercury. Two bright stars, Antares and Spica, are also shown very close to the same line; they help to delineate the ecliptic when the planets are not present. The ecliptic passes through the twelve constellations that make up the zodiac. Four of them are easily visible in this sky scene (until the brightness of the waxing moon overpowers them): Libra, Scorpius, Sagittarius, and Capricornus. The ecliptic continues below the horizon, to the east and west of this scene, where its northern branch is much higher in our sky when it is visible and is best seen in the early evenings of February, March, and April.

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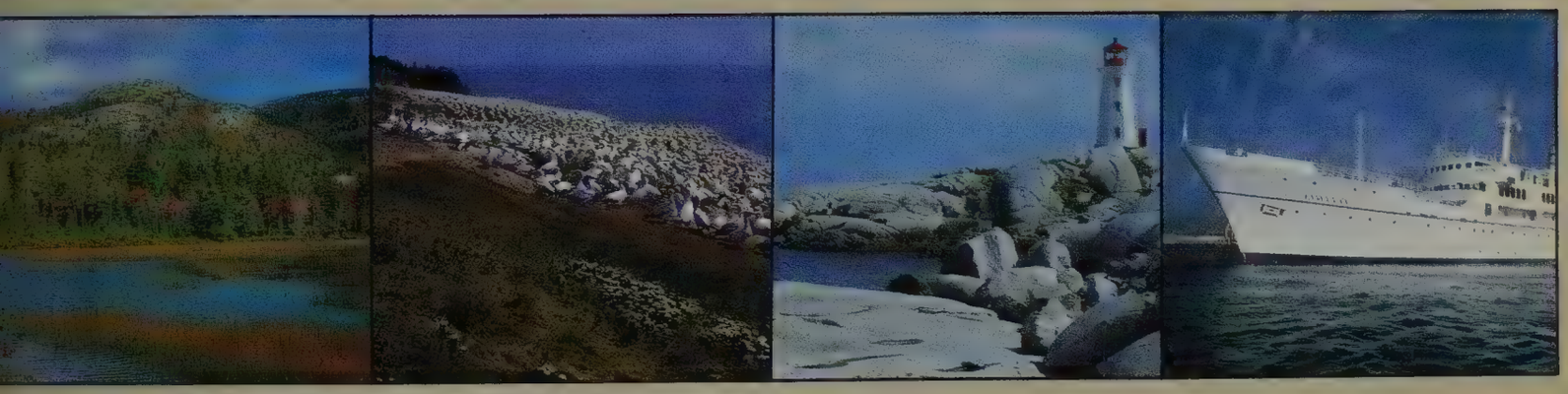

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Fish Market Taxonomy

At 4:00 A.M. New York's Fulton Fish Market is as raucous as a midway—with ice and fish shimmering beneath the street lights, wood crates burning in steel barrels, dealers barking orders, and trucks crowding the streets on the east side of lower Manhattan.

"Hours before daylight every morning of the week," wrote Thomas DeVoe in 1862, "may be found here fishwagons, cars, and other vehicles from the various public markets, meat-shops, and street peddlers, and villages, for their daily supplies; which part of the business is generally over by seven o'clock A.M." DeVoe would have no trouble recognizing the place today. Among the great fish markets of the world—Tsukiji in Tokyo, Rungis in Paris, Billingsgate in London—Fulton is an anachronism. Men still crack crates with hand axes, pick fish with wood-handled metal hooks, pack them up, and cart them through the jammed streets on wooden hand trucks with ironbound wheels.

Amidst this early morning ruckus, Norma Feinberg, collection manager of the Ichthyology Department of the American Museum of Natural History, is bargaining with a dealer for fish she doesn't have the least interest in eating. The heavy glasses on her broad face make her appear unflappable and resolute in her preference for some reddish-skinned, unappetizing-looking specimens with puffed, prickly bodies. They are armored sea robins, and she is sure she wants them.

"What are these things?" the dealer finally asks his partner.

"Don't know. I've been working at this stand twelve years, and I've never seen them before."

"How much are they?"

"Fifty cents a pound."

Norma takes the lot of them, fourteen, which, more bone than flesh, come to less than five dollars. She puts them in one of her plastic shopping bags and moves on. This has been a good morning for collecting. On Mondays, fish come in from southern ports, and there are shipments of kingklip from Uruguay, pompano from Florida, sea trout and redfish from the Gulf Coast, blue runner and grunt from off Caribbean reefs. Norma, in flapping pants and gray running shoes, goes round to all the stands, adroitly sidestepping puddles of melted ice; ducking hanging metal scales; dodging piled crates, swordfish, tuna carcasses, and pallets of gleaming Atlantic salmon farm bred in Norway; and heeding calls of "watch your back!" from workers leaning into loaded hand trucks. She has already acquired a wolf-

Above: Early morning at New York City's Fulton Fish Market. Right: American Museum ichthyologist Norma Feinberg on a collecting foray at the market.

All photographs by Barbara Mensch

Richard Lord, fish salesman Anthony Rovi, Feinberg, and triggerfish

fish, ladyfish, lemon shark, and the sea robins. Not for eating. "There are some fish," she says, "you just don't eat." What you do with them is bring them back uptown and preserve them as specimens for the Museum's collections.

During the last couple of years, the American Museum of Natural History has become a regular customer of the Fulton Fish Market, itself a kind of natural history museum. For more than 150 years the fish market has exhibited on the same site hundreds of species of fish and shellfish—albeit only at night—washing down its displays and closing its gates just as the rest of Manhattan is beginning its own early morning clamor.

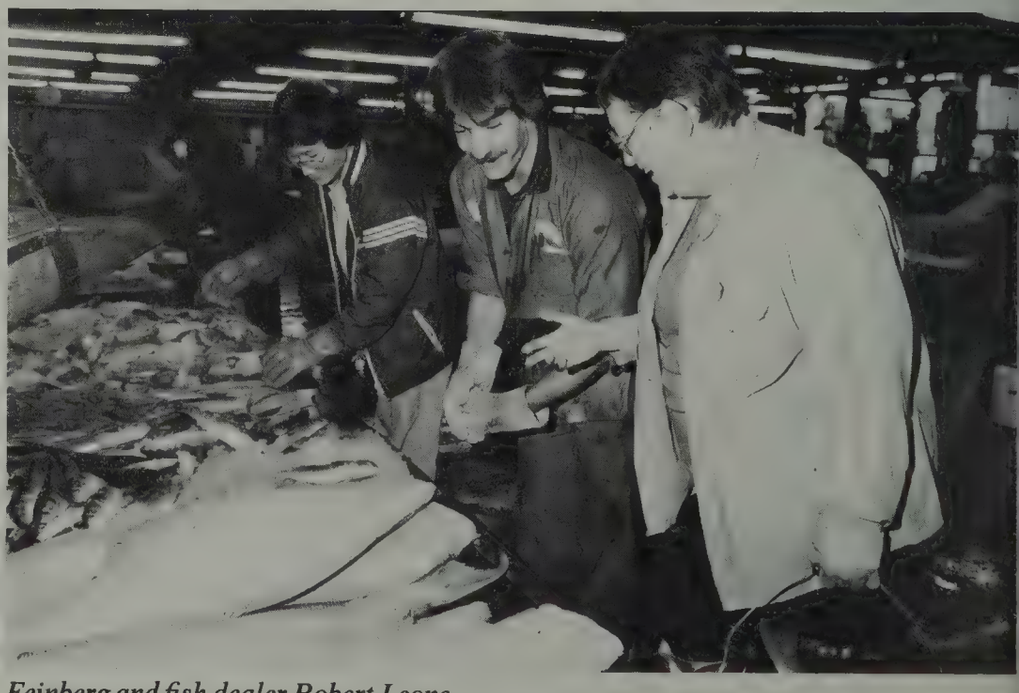
Fulton has always been the major fish market on the east coast. On any day there are half a million pounds of fish on consignment to the eighty-five wholesalers crowded into a four-square-block area along both sides of South Street in lower Manhattan. Here, in the shadow of the modern commodity exchanges, fish brokers work in brick row houses behind whose unchanging, ramshackle façades are packing houses, cold storage and fillet houses, and New York City's last finnan haddie smokehouse. Outside, fish are on display for restaurants and retail markets, for chefs, the occasional tourist, and the even rarer buying taxonomist. For the last there is plenty available. Most of the fish sold at Fulton is in the round, that is, whole and uncut. Trawled, hooked, or trapped, the fish have gone from water to fishing boat to dock, and by truck or plane to Fulton. They have come from the Gulf Coast, the West Coast, South America, the coast of Africa, the North Atlantic, Caribbean, Mediterranean, or the Pacific. Nearly every group of fish is represented. There are the common flounders, cods, carps, snappers, and basses. There are croakers and drums, mackerels and herrings. There are also fish less common to American markets—grunts, jacks, groupers, and angelfish. And then there are the rarities that appear among the others, fish that got caught up in the nets and made their way to Fulton, where they may be dubbed by the dealer something appropriate to the moment and, if a buyer can be found, sold.

In this striving for profits, science was suffering until Richard Lord began to take an interest in the taxonomic possibilities at Fulton. Hired three years ago to run the market's information services, he decided there might be more to improving the public's perception of fish than getting recipes into the newspapers. There was something to be said for fish that was not being said—beef, after all, could be a broiled dinner just as well, and in comparison, cattle live a pretty tame existence. Lord decided that fish were underappreciated for the variety in their kind and lives. He began to study up and spread the word. He came first to the American Museum where Gareth Nelson, head of the Ichthyology Department, happened to be on the lookout for fish, especially their skeletons.

"Most of what a fish is, is skeleton," is the way Nelson puts it. Unlike other vertebrates a fish's bones continue to grow long after it reaches sexual maturity. Understanding the growth of a fish species requires comparisons of skeletons from various stages of its life. "You can't look at a single specimen and comprehend the species from it. There are variations from the beginning of its life to the end." And variations among varieties. The skeletons of anchovies, for instance, are a Nelson specialty. He can distinguish a Pacific coast species from an Asian species by a look at its bones. Nelson's enthusiasm for skeletons is such that for recent studies on ladyfish he struck a deal with an Alabama fishing tournament.

"In the past," says Nelson, "people didn't pay attention to collecting what was commonly available. But what is commonly available may not always be so. Richard finds fish that are interesting and unusual, and much of our recent skeleton collection is due to his efforts. I was suprised by the diversity at the market." Richard Lord is compelled by it.

A slight young man with a fair complexion, Richard speaks in a soft British accent that contrasts strikingly with the more



Feinberg and fish dealer Robert Leone

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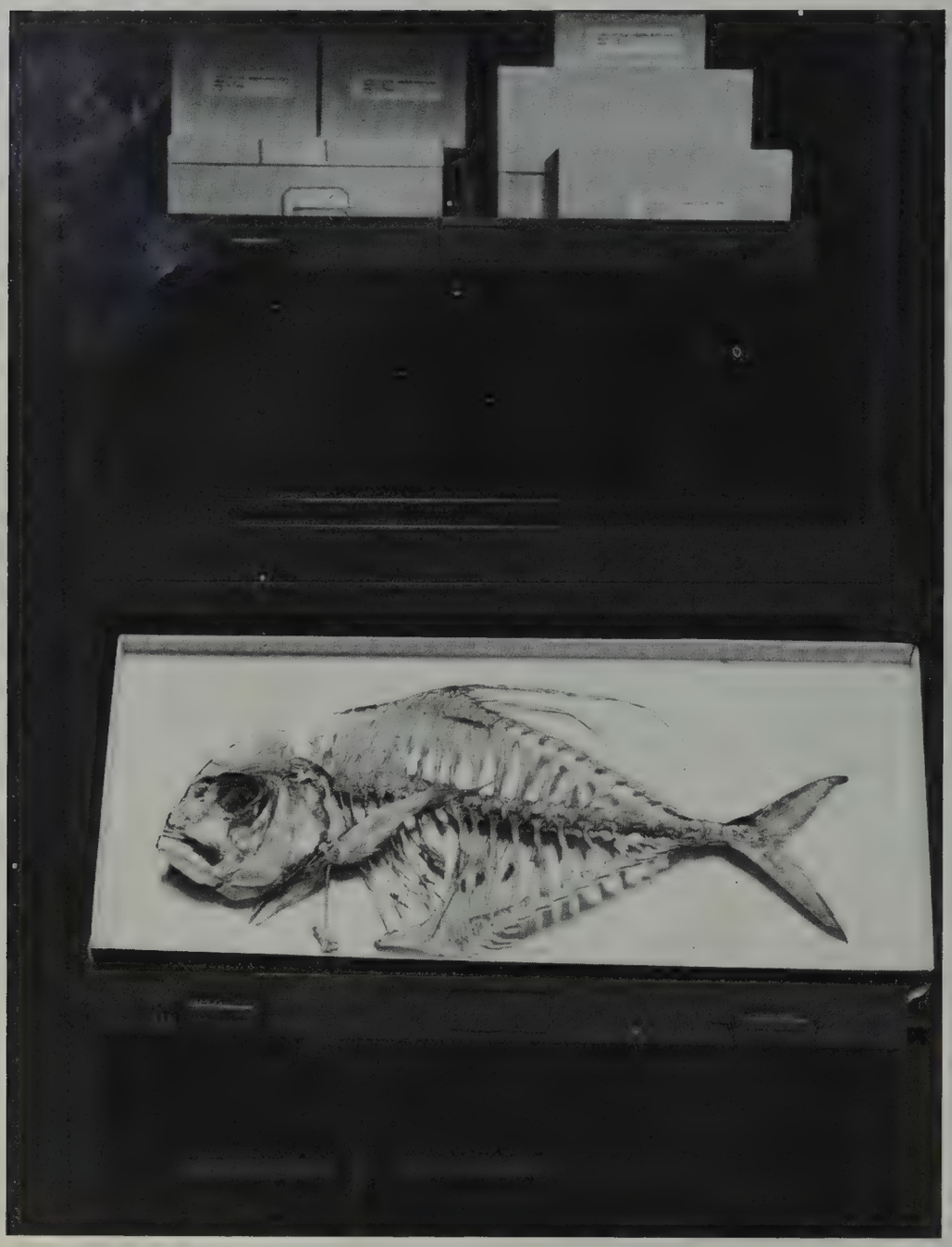
*Below: The skeleton of an African pompano (*Alectis ciliaris*), caught by commercial fishermen and collected by Feinberg at the Fulton market.*
Right: Lord and Feinberg leave the market.



strident market voices. Yet he is an aggressive lecturer on his frequent morning tours of the market, raising specimens to make a point, opening their jaws and gill flaps, noting aloud the count and thrust of their teeth to prove an identification, spreading their dorsal fins to count their spines and rays. Lifting a fish from among those on a dealer's steel table, Richard gets quickly into the spirit of the pursuit.

"The jacks are wonderful fish, structurally beautiful fish from the tropics and subtropics with distinctive forked tails. They are red muscled, like tuna, because they swim a great deal. The flesh is filled with capillaries to supply blood to the muscle." Such strong muscular actions in tuna, for example, can aid the fish in producing body heat despite its being cold-blooded. In contrast, flounders and flatfish are white muscled, rarely moving, spending most of their lives at the bottom. Crevalle are the most common jacks in the market, and the collection on this table all appear about the same. But one fish catches Richard's eye.

"What's this one?" he asks the dealer.

"An amberjack."

Richard looks again, lifts it up, examines its long pectoral fins and the yellow tint of its body. "An amberjack," Richard says, "has a black line through its eyes that runs up to the top of its head."

"Well, maybe it was hanging around with too many crevalle jacks."

"How much do you want for it?" Richard asks.

"Take it," the dealer says, aware now that a potential buyer scrutinizing the jacks has been listening in.

Richard packs the fish in a bag an moves on with his tour. "He may be happ with amberjack, but I'm not. We'll look up later."

Fish are inevitably known by an array o names. Anglerfish are monkfish, ugly fish, goosefish, bigmouth, and lotte. Wol fish are called ocean catfish, but they ar not true sea catfishes. Richard says tha red porgies are sold to restaurateurs a pink snapper and are sometimes served a something called white snapper. "Snap per," says Richard with some exaspera tion, "is the most abused name in the mar ketplace." So abused, in fact, that there i a law declaring pink, triangular-heade *Lutjanus campechanus* the only fish tha can be rightfully called a red snapper And yet there are at least twenty specie of snapper in the market out of some thre

hundred worldwide, and they come from every sea. Many are red, redder than the legal red, and most are just as good to eat. There is the vermilion snapper, *Rhomboplites aurorubens*, with rounded head and faint diagonal lines on its back; the dealers call it American or South American beeliner. There are yellowtail snappers, queen snappers (called doorbats in Florida), lane and silk snappers at Fulton.

Groupers, which include scamps, gags, kitty mitchells, and coneys, are also often misidentified. The red grouper is the most common; the snowy grouper and marbled grouper, rarer. Yet even the more common specimens can be a challenge to identify. The fins of the yellowfin grouper, for instance, lose their color quickly, so a grouper in the market with yellow fins is most likely not a yellowfin grouper but a yellowedge grouper. Fish are changeable. They display different colors depending upon their age and sex and surroundings. Many, like the black sea bass, are hermaphroditic, beginning life female and becoming male later on.

To add to the confusion, the fish market has a taxonomic system of its own. On one wholesale stand a black-barred hogfish *(Bodianus speciosus)* from Senegal is being sold as a parrotfish. The hogfish, Richard points out, is a wrasse with canine teeth, while the parrotfish has incisors and fully fused dental plates; its teeth are clenched and jutting. "The United Nations Food and Agriculture Organization sent me its six-volume *Fishes of the Eastern Atlantic* by mistake. It was free and I never thought I'd use it, but it's turned out to be very useful."

Whiting is the most common fish in the market. It is available year-round, migrating along the Atlantic coast from New Jersey to Cape Cod. Sometimes called frostfish, it is found off the coast in winter. During a spring tour of the market, Richard picks up a limp specimen from a wooden crate and pokes it to show how soft the flesh is. It had been feeding heavily on sand eels, he explains, and the digestive enzyme action has made the flesh go soft. In February, when the fish feeds less, the flesh is firmer. Turning the slim, eight-inch fish in his hand reveals a hole in the abdomen. This particular fish, Richard says, has what is known as belly burn. The enzyme activity was so great that it continued after the fish died and burned right through its stomach and flesh. In the spring, Richard adds, fish should be eviscerated soon after being caught. Enzymes are great spoilers of fish. Fish crushed in nets or bruised in shipping will spoil more quickly as enzymes seep through the broken cell walls and begin to act on the flesh.

How fresh a fish is, is not so much a matter of how long it has been out of the water but at what temperature it has been kept. Bacterial spoilage usually increases with rising temperature. In warm-water fish, bacterial growth is inhibited by packing in ice. Bacteria in cold-water fish, however, may more readily adjust to the cold temperature and then may grow even more quickly. Marine fish spoil more quickly than freshwater fish. Since the oceans are more saline than the body fluids of the fish itself, water in the fish's system is continually being drawn out by osmosis into the ocean. The great struggle of marine fish is to keep from dehydrating. So they drink as they swim, expelling salt through their gills. After death the chemicals that control this process of osmoregulation break down quickly, causing spoilage. (Freshwater fish have the opposite problem. More saline than their environment, they absorb water and must continually urinate.) In sharks and rays, one of these chemicals, urea, breaks down after death to produce ammonia, giving the fish a foul taste unless it is bled or eaten soon after capture.

The greatest volume of fish comes into the Fulton Fish Market in the spring and fall during migrations and spawning runs. This spring, Richard counted thirty species he had never seen before. Many of the fish in the market then are filled with roe—not only the shad but also the mackerel, flounders, sea robins, and sole. Although the roe, Richard suggests, is tasty, some—such as in the bowfin, gars, and pufferfish—is toxic.

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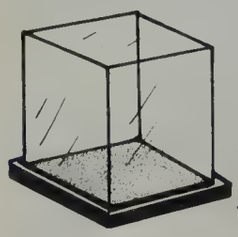

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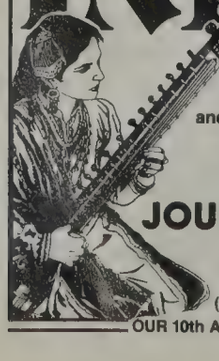

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Richard presents the market's displays with a curator's ardor. Here are eels squirming in gauze sacks, land snails from Haiti in hand-woven wicker baskets, iridescent blue-and-gold-hued dolphinfish called mahimahi (one morning a great deep-bodied male and a slimmer female were displayed together in the same wood box). Here are toadfish, boarfish, goatfish in shimmering stacks; clams from British Columbia in Idaho potato bags; tilapia farmed in Israel and Jamaica; Dover sole from Senegal. Among a display of whiting are small, red, northern Maine shrimp. Black, three-inch-long skate egg cases, called purses or mermaid's purses, are with fish caught by offshore netters; baby mackerel are found in the display of anchovies caught off Portugal; cownose rays caught up in the trap nets of Chesapeake Bay fishermen come in with the croakers; dogfish trapped in the nets of New England fishermen come in with the fish from northern ports. Richard's prize find, a twenty-five-pound long-finned cigarfish, which went to the Museum's collection, was discovered in a bin set out for disposal. Given the Museum's tight collecting budget ($20 a month), the already filleted racks of sole, flounder, and cod found in the dumpsters after the market closes are a ready and free source of specimens. The cigarfish had come in with flatfish from a fisherman who trawled off Long Island Sound. Richard called the trawler captain, who admitted he hadn't caught it but had gotten it from another fisherman who was hook fishing for tuna, shark, and swordfish. That captain just happened to be in port and Richard was able to ascer tain that the rare fish was caught som 120 miles south of Montauk, Long Island

"People become specialists in differen aspects of identification," Richard says "Here, I see so many fish in their natura colors, that I'm able to recognize them b seeing them this way. Learning the classi fications is a matter of learning to identif the families by their body shape, ther even new species can be identified mor easily. Norma had problems at first rec ognizing the fish in all their colors. If I sav a fish that had been in alcohol for a year probably wouldn't recognize it." Awar that Richard and Norma are after th unusual, the dealers will often set aside things they don't recognize. "It ofter comes to me as a challenge," Richard says. "They will say 'I bet you haven't seer anything like this before,' or 'Let's see i you can name this one.' " One morning a dead dogfish gave birth to six young in a dealer's stall. This small shark, which gives birth to live young, was caught with its embryos just about fully developed and they lived off their yolk sacs until they were born in the market. It is, Richard says, a not uncommon summer phenome non. Dogfish are often taken as a nuisance fish, and although they could be of eco nomic value, they are rarely eaten. Giving birth to live young may make them highly susceptible to overfishing, and Richard fears the fish stocks are being depleted and wasted. The interest of the dealers in Richard's pursuit varies. One morning Richard immediately recognized a lone golden-red fish on a stand as a rarely seen

At the American Museum

At The Planetarium

Wonderful Sky, the Planetarium's special show for preschoolers, is back at the Sky Theater. This show takes children on a journey of exploration and encourages them to sing along as they learn about weather, rainbows, sunsets, distant stars, phases of the moon, and other objects in the sky. Show time for *Wonderful Sky* is Saturday, August 2, at 10:00 A.M. and noon. For additional information and reservations call (212) 769-3299.

Wolf Lore

In conjunction with the exhibition *Wolves and Humans*, two speakers will be at the Museum to discuss wolf ecology and folklore. In *Wolves of Many Dimensions,* Thursday, August 21, at 7:30 P.M., in the Main Auditorium, biologist L. David Mech will talk about current research into wolf behavior and folklorist Ellen Stekert will survey both popular and little-known wolf lore. Tickets are $3.00 for members and $5.00 for nonmembers. For more information call (212) 873-1327.

In The Galleries

Lost and Found Traditions, an exhibition of contemporary Native American art forms, will continue to run in Gallery 1. *Wolves and Humans: Coexistence, Competition, and Conflicts,* which examines the biology and folklore of the wolf, may be seen in Gallery 3.

Naturemax

Three new films will debut in the Naturemax theater this summer. *Nomads of the Deep* probes the mysterious habits of the humpback whale at rest and play; *Skyward* explores the relationship between man, birds, and the environment; and *On The Wing* portrays the contrast between natural and mechanical flight. For show times call (212) 496-0900.

ss called a creole fish. To the dealer, wever, it was a velvet snapper and going r three dollars a pound.

When he gets a fish for the Museum, chard takes it home to Hoboken by ain, photographs it, and if he doesn't ow what it is, will commute back with s now often frozen specimen and give it the Ichthyology Department. The jack found on the stand turned out, after an entification session on the floor of his amped office at the market, to be a llow jack, a rare offshore fish in tropical aters. After talking with Norma at the luseum he filleted it, careful not to dam- ge the bones.

Barbara Brown is in charge of the bones fishes at the Museum and she says the lationship with the Fulton market has een a good one. "All they want is the eat, all we want is the bones." Not that orphology isn't important in the fish usiness. Fish with large heads, like pol- ck, yield less flesh per pound. The fan of artillage in skate wings (there are cases of hem at Fulton) makes the flesh difficult o get to and so cheaper. Despite the veetness of its flesh, the triggerfish goes nappreciated. Its tough skin—it is called leatherjacket in New Zealand—pro- cts it from the spines of the sea urchins it reys on. Perhaps in deference to these pecies as well, the fish's eye is located far rom its mouth. This makes for a broad sh whose fillet resembles the fillet of a atfish like a turbot. In the Caribbean, the riggerfish is often called turbot.

Since January 1985, some three hun- red skeletons have been added to the Museum's collection. Once Norma brings ack the fish and fillets them, Barbara Brown oversees the final preparations. The eyes and as much flesh as possible are emoved and the specimen is allowed to ry before being given to the bugs. The ugs, as they're known, are dermestid bee- les, whose larvae and adults will clean a arcass to the bone. A hundred thousand ugs swarming over a three-foot fish could ick it clean in a day. Once their work is omplete, they have to be removed before hey eat their way through the cartilage nd leave nothing but a pile of discon- nected bones. After the skeletons are reated to make sure no bugs still survive, hey are cataloged and stored in card- board boxes in crowded steel cabinets.

One cabinet contains all mackerels—a arge king mackerel in one box, a Spanish nackerel in another. There are boxes of flounders, soles, and jacks. Gareth Nelson akes no less pride in his curatorship than Richard Lord, as from each box of bones he conjures up a living fish.

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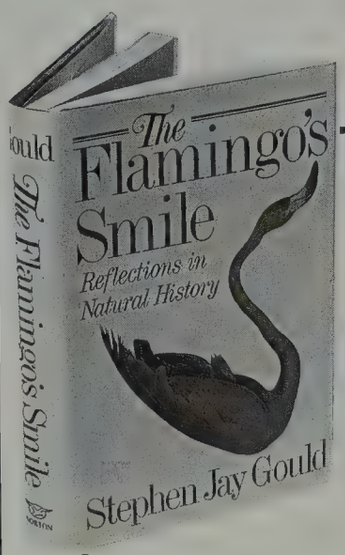

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Hooking a Snook

The commercial line of supply for fresh fish is a delicate mechanism

by Raymond Sokolov

Fish are such a headache. If they're not slurping up mercury or some other industrial pollutant and making themselves inedible, they're dying out because they can't survive intense fishing. Shellfish can give you hepatitis or other diseases. And even healthy seafood isn't much good to eat if it isn't fresh from the hook.

This business about freshness is no food snob's exaggeration. People who think "fresh frozen" fish or even "fresh" fish bought at the supermarket is just as delicious as the bright-eyed, clean-smelling, caudal-fin-flapping, really fresh fish I am mongering here must never have tasted a fish before time and the hand of man had degraded it.

I used to read statements like that and shrug. Then I ate swordfish freshly plucked from the harpoon on Cuttyhunk Island off New Bedford, and the scales fell from my eyes. There is no pun intended here, for as any ichthyologist or rabbi will tell you, a swordfish does not have true scales, the sort that can be scraped off without damaging the fish's flesh. This is why it is not kosher. But it is most delicious, especially in a place such as Cuttyhunk, where miles of ocean and highway, three-tiered commercial transactions, and the other interferences of modern urban life do not stand between the luncher and the fish.

While I reveled in this discovery, in the simple dining room of a small hotel overlooking the Atlantic, it occurred to me that I would not soon repeat the experience. In fact, I never have with swordfish because I haven't since been close enough to a harpooning ground.

The commercial line of supply for fish is a delicate mechanism under the best of circumstances, but fish lovers have even more to worry about at the moment than fanciers of other kinds of food. To some degree, they have their own appetites to blame for shortages and overfishing. Last spring, New York newspapers sounded the alarm for redfish. Not too many years ago, no east coast editor would have printed an item about this appealing resident of the Gulf of Mexico. Then came the mad vogue for Cajun food from Louisiana. The Cajun chef Paul Prudhomme wrote a best-selling cookbook, publicized himself with even more skill than he had in the kitchen, and put redfish on the map. His highly spiced recipe for blackened redfish began appearing on menus from Block Island to Marina del Rey. Often the fish actually served was not redfish, but often it was—too often for the much hunted fish to stand the gaff. We can expect strict fishing regulations to be imposed on the commercial catch. Or the gulf states may ban commercial fishing of redfish altogether.

This is what Florida, for example, has done with its legendary game fish, the snook. I am talking about the subtropical fish known to science as *Centropomus undecimalis*. Nonichthyologists sometimes refer to the snook as linesider because of the very noticeable thin black line that runs from one end of the snook to the other, separating its yellow-green-tinted gray back from its silver belly. In south Florida, the snook is also called soapfish, because it supposedly tastes like soap unless the skin is removed (I did not test this notion, but it is universally believed by sport fishermen, who systematically strip off a snook's skin before cooking it). It would be interesting to see if the legend is true and if the skin could be left on during cooking—a mechanical convenience—and then stripped off, without leaving its saponaceous flavor behind. But nobody, least of all a short-term visitor, would ri ruining a snook just to shoot down a har less and probably true claim.

Everyone in the snook world tells y that snook used to be thrown away un some clever or desperately hungry or e tremely finicky ichthyophage cooked o without its skin and found it good, ve good. By one account, this snook pione was black, and the good news about *undecimalis* percolated only later into t white community. Today, the snook prized for its mild flavor, and sport fishe men pursue this elusive and canny fight in the shallow, mangrove-bordered inle of Florida's western coast with the ze that Ponce de León once focused her abouts on the location of the fountain youth.

There was a certain poignancy in th connection. The very same week in Ma that I journeyed south for my lon awaited appointment in Sarasota wi snook guide Scott Moore, fishing f striped bass in New York waters w banned on account of possibly dangero levels of contamination from polychlo nated biphenyls (PCBs). A favorite loc fish was being banned, so soon after i rescue from the threat of an enormo landfill in its lower Hudson River habita (The landfill would have carried the su terranean southernmost end of a propose highway called Westway, which aft years of litigation, was canceled, in r small part because of its putative menac to the striped bass population maturing i the waters off Manhattan's West Side.)

It was a week full of piscatorial ba news. From Massachusetts came th sound of an ill-mannered quarrel betwee friends of the salmon and friends of th shad. Two successful fish replenishmer programs were in a collision whose epicer

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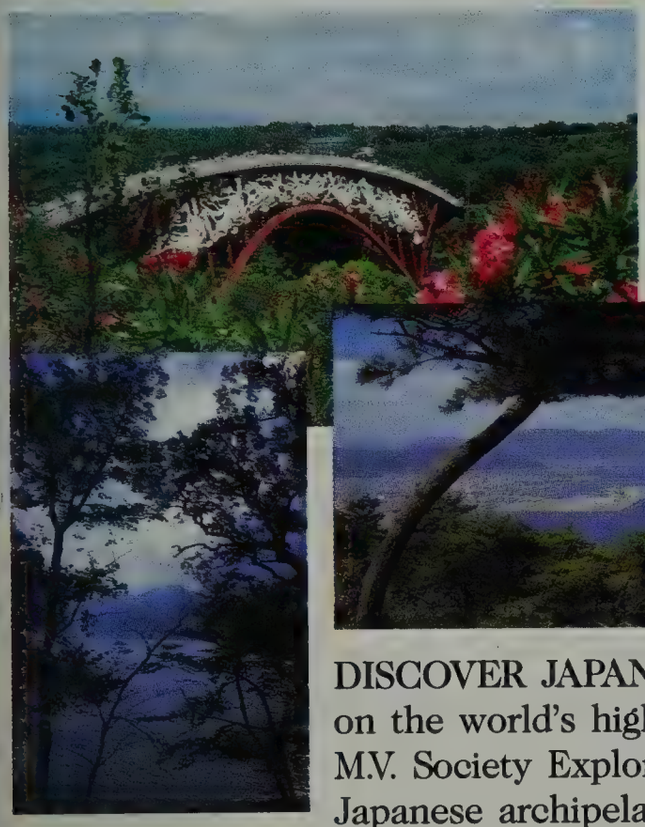

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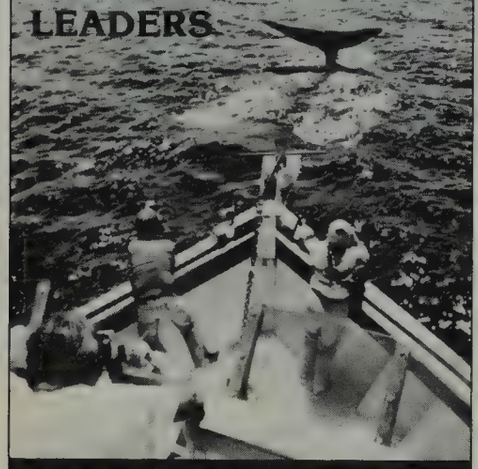

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ter was a fish lift at a dam on the Connecticut River near Holyoke. The lift is crucial to moving salmon upstream. Since a new program had succeeded in restoring salmon to the river for the first time in 200 years, and since a thousand salmon were expected to make the run this year, the folks from the Connecticut River Atlantic Salmon Commission were understandably miffed when the lift was shut down to permit the trapping of shad. Massachusetts is a net exporter of shad to nearby states, and this restocking program has multiplied the shad population in geometric proportion in twenty years. Nearly half a million shad now reach the Holyoke lock, a hundred times the number estimated in 1955. But a closed lift might kill the waiting salmon. In a compromise, a daily limit was placed on each day's shad trapping.

Back in Florida, the snook is also carefully watched. The ban on commercial fishing dates to 1957, when the catch had fallen from an annual peak of 800,000 pounds to less than 500,000. The fishermen had been cutting into spawning stock, but landlubbers had also put pressure on *C. undecimalis*. Their avidity for shorefront property destroyed the snook's spawning habitat. As condominiums multiplied, mangroves were cleared away and their roots were no longer available to shelter the snook's young. Rainwater cascaded in sheets from paved surfaces into the shallow, warm, brackish coastal inlets where snook had thrived, lowering the salinity to levels unpropitious for the fish. Oxygen was depleted by algae feeding on pollutants. More people brought more pesticides; their power boats contributed gas and oil.

These days even sport fishermen are forbidden to take snook in their spawning season (June through August) and in January and February, when cold makes the fish sluggish and too easy to catch. In the other months, sportsmen can legally hook two snook per day if the fish are twenty-four to thirty-four inches long or one larger snook per day. (Penalties are stiff. In July 1985, four poachers apprehended by the Florida Marine Patrol with fifteen fish in their boat were fined $500 each and sentenced to 100 hours of public service work and six months probation in lieu of jail terms. It was not possible to determine what happened to the fish, which had been held in a freezer as evidence. But if the arresting officer got to eat the snook, that seems like an excellent reward and an incentive for vigorous enforcement of a good law.)

The very largest snook measure more than four feet and weigh more than fifty pounds. All snook are wary and hard approach. From shallow, clear water they can detect a boat at close range or person standing on a dock. They do n always rise to the bait. And they fight lik hell, cutting themselves loose with the razor-sharp gills and racing into nearb palisades of projecting mangrove root where they foul and snap fishing lines.

I learned about all this firsthand und the tutelage of Captain Moore, as h popped the *Primadonna II* into variou environmentally protected inlets on th periphery of Tampa Bay. Having netted few dozen minnows in an eight-foot purs seine, Moore struck out for shallow wate poling in the last few yards to surprise th fish. I hooked six and landed none. A mo experienced and venerable local sport man landed his limit, adeptly lowering th tip of his graphite rod into the water t keep the lightweight line from snaggin when the fish headed for the mangrove They came out of the water looking mea with protruding lower jaws and bon mouths; one, measured and then quickl liberated, was longer than the yardstic fixed to the floor of the open boat.

This Hemingwayesque angler was gra cious enough to share his catch with me. I was baked that night by his wife back i Sarasota, baked just to the point of idea tenderness.

Raymond Sokolov is a writer whose spe cial interests are the history and prepara tion of food.

Skewered Snook

(Adapted from *The Complete Book of American Fish and Shellfish Cookery*, by Elizabeth Bjornskov, Alfred A. Knopf)

- 1 pound skinned snook fillet
- ¾ cup lime juice
- ¼ cup oil
- 2 tablespoons grated onion
- ½ teaspoon salt
- 6 strips bacon
- Lime wedges

1. Cut snook into ¾-inch cubes.
2. Mix a marinade of lime juice, oil, onion, and salt. Add fish and marinate, covered, for several hours at room temperature.
3. Cook bacon in a skillet until it has just begun to brown. Drain on paper toweling and cut into pieces large enough to skewer.
4. Alternate fish and bacon on skewers. Grill over medium-hot coals until the fish turns opaque all the way through and begins to flake. Serve with lime wedges.

Yield: 3–4 servings

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A Sanguine Approach

Charles Darwin never set foot on the mile's worth of Galápagos rock that is Wenman Island, but a few of his famous finches reside there. One species, Darwin's sharp-beaked ground finch, lives on several Galápagos isles, but only on Wenman has it taken to supplementing its seed and insect fare with blood, thus earning the name vampire finch.

On finding a roosting sea bird, such as the masked booby pictured here, the finch uses its long, slim bill to stab the heavily vascularized base of the bigger bird's tail and wing feathers. The first trickle of blood draws a small crowd of finches and all rally round for a taste, squabbling and hopping eagerly on the ground or perching on the booby's roomy back. During these encounters the sea bird shifts and shrugs and occasionally resorts to pecking the "vampires" off. Having tapped yet another Galápagos food source, the satiated finches fly away for the time being.

Photographer Tui De Roy joined an oceanographic expedition that visits uninhabited Wenman once a year. The group landed in November 1982, when the island was in the grip of El Niño. Taking advantage of a midday lull between downpours, De Roy scaled some cliffs capped by a plateau. There she witnessed the bird parasitism, peculiar to Wenman, that was first noted scientifically some twenty-five years ago. After recording the ritual on film, she headed back to the ship as another storm assailed the usually arid island, and El Niño made its deadly, wet, warm way east.—*J.R.*

Photograph by Tui De Roy

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Authors

Studying the influences of strip mining on the chemistry of streams led **Branley Allan Branson** (page 30) to undertake long-term studies of the effects of mining on insects and fishes. The first reports of his work, which began in 1969, were published in *Natural History* in November 1974. Branson, an ichthyologist, has worked closely with the U.S. Forest Service in Kentucky. He teaches at Eastern Kentucky University and is a Kentucky Academy of Science Distinguished Scientist. Additional information on strip mine pollution can be found in *Ecology and Reclamation of Devastated Land,* vol. 1, edited by R.J. Hutnick and G. Davis (New York: Gordon and Breach, 1973).

Photographer and writer **Tui De Roy** (page 84) had the rare good fortune to grow up on the island of Santa Cruz in the Galápagos, and she still lives there today. In her book *Galápagos: Islands Lost in Time* (New York: Viking Press, 1980), she tells of the beauties of the islands, their history, and her own childhood, commenting that "I would not trade my life experiences for anyone's." In 1982 she visited the small northern outpost of Wenman Island as a guest of the National Oceanic and Atmospheric Administration's Oceanographic Expedition. There she recorded the bizarre feeding behavior of one species of Darwin's finches, sometimes known as the vampire finch, the subject of this month's "Natural Moment." The photo was taken about noon on a cloudy day. De Roy used Kodachrome 64 film and an Olympus OM1 with a Zuiko 135-mm lens. The famous Galápagos finches, so often cited as examples of speciation, are the subject of David Lack's study *Darwin's Finches: An Essay on the General Biological Theory of Evolution* (Gloucester: Peter Smith, 1968).

"Raccoon dogs," notes **Hiroshi Ikeda** age 38), "are said to be able to bewitch ople in Japan." He cites his own ex-rience with the popular mammal the panese call *tanuki:* "I happened to ke up raccoon dogs as my research bject for a master's degree. I got more d more involved in them, becoming lit-ally enchanted by their cuteness and teresting behavior." Ikeda continued s fieldwork for several years, conduct-g the first in-depth study of these om-vorous canids. He received his doctor-e from Kyushu University in 1982. urrently an administrator in the Monu-ents and Sites Division of the Agency r Cultural Affairs in Tokyo, Ikeda now ajoys studying the lore of raccoon dogs recorded in Japanese literature. For ose who want to know more about anids, Ikeda recommends Christopher ever's *Naturalized Mammals of the Vorld* (London: G. Longman, Ltd., 985) and Michael W. Fox's *The Wild anids: Their Systematics, Behavioral cology, and Evolution* (New York: an Nostrand Reinhold Co., 1975). The nildren's book *Once Upon a Time in Ja-an* (Tokyo: Kondansha, 1985), com-iled by Sayumi Kawauchi and trans-ated by Ralph F. McCarthy, contains vo stories of raccoon dog escapades as ell as other Japanese tales.

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Associate professor of biology at the University of Connecticut at Storrs, **Charles S. Henry** (page 46) traces his research on green lacewings back eighteen years, when, as an undergraduate, he first attempted to record their courtship songs. Since then he has looked at various aspects of lacewing biology, including communication, reproduction, and speciation. In the future, he hopes to study how green lacewing larvae defend themselves from the ants that tend the aphids on which the larvae feed. Henry also hopes to return to research on owlflies, the subject of his dissertation. For work and pleasure, he maintains an interest in sound reproduction, occasionally investing rashly in expensive audio equipment. On the quieter side, Henry restores old cars, especially V-8 Fords of the early 1950s. For further reading on lacewings, he suggests *Biology of Chrysopidae,* edited by M. Canard, Y. Séméria, and T.R. New (The Hague: Dr. W. Junk Publishers, 1984) and Randy Thornhill and John Alcock's *The Evolution of Insect Mating Systems* (Cambridge: Harvard University Press, 1983), which offers a thorough analysis of insect reproductive behavior, including song.

Tom Eisner (page 54) has always loved photography. "My mother was an artist and photography has been my way to compose pictures," says Eisner (left). The Schurman Professor of Biology at Cornell University, Eisner's field of interest is animal behavior—mostly insects. Fieldwork has taken him throughout the United States, Latin America, Australia—and his own backyard, the perfect place to gather fallen leaves. **Edward O. Wilson**, who provided the essay that accompanies Eisner's photographs, is Baird Professor of Science and curator of entomology at the Museum of Comparative Zoology at Harvard University. An evolutionary biologist, Wilson concentrates his research on the social insects, sociobiological theory, and systematics.

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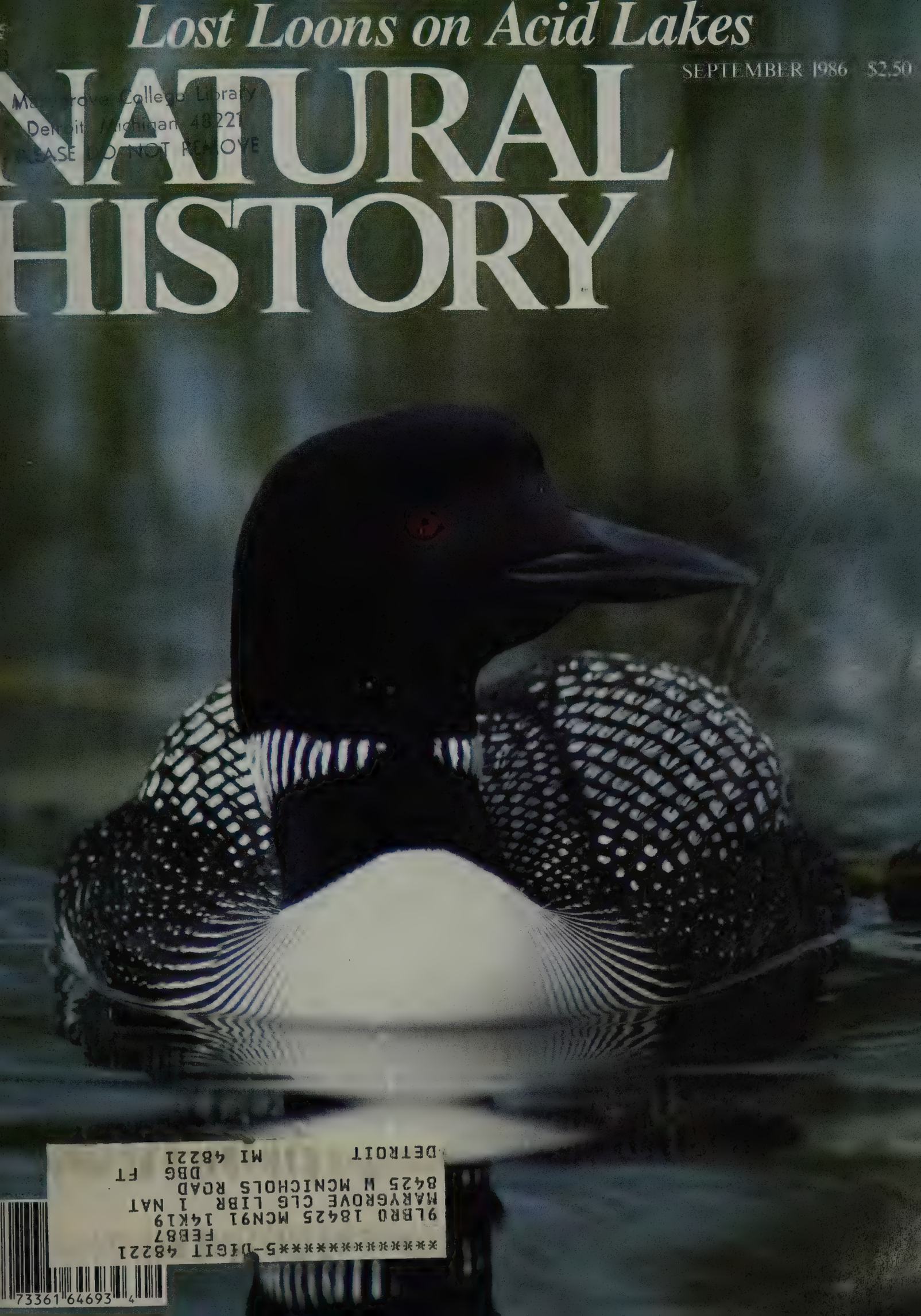

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Vol. 95, No. 9, September 1986
American Museum of Natural History, New York, N.Y.
Robert G. Goelet, President
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2 Letters

4 Speaking "Indian" in Louisiana *Emanuel J. Drechsel*
Traces of an extinct language persist in the eddies and bayous of southern Louisiana.

16 This View of Life *Stephen Jay Gould*
The Archaeopteryx Flap

26 The Human Strategy *R. Lincoln Keiser*
Foul Shots and Rifle Fire

34 China's Venerable and Glorious Architecture *Xu BoAn and Guo Daiheng*
The great structures, including wooden ones more than 1,000 years old, are testaments to the country's master builders.

44 Getting Along in Appalachia *Jerry O. Wolff*
When resources are abundant, different species of mice survive side by side without competition.

50 The Island Sweepstakes *Paul Y. Sondaar, illustrations by D. L. Cramer*
Dwarf animals—now extinct—once populated many Mediterranean islands. Why?

58 Lost Loons of the Northern Lakes *Robert Alvo*
When lakes turn acidic, they become clear, blue, lifeless, and silent.

68 This Land *Robert H. Mohlenbrock*
Red River Gorge, Kentucky

74 Reviews *John R. Alden*
In Search of the Woolly Mammoth

80 The Living Museum
10th Margaret Mead Film Festival

82 A Matter of Taste *Raymond Sokolov*
Let 4,000 Flowers Bloom

86 Celestial Events *Thomas D. Nicholson*
A Planet-studded Evening Show

92 The Natural Moment *Photograph by Jeff Rotman*
Tail of Woe

94 Authors

Cover: *The common loon is becoming less common on many northern lakes. Story on page 58. Photograph by Peter M. Roberts; Wildlife Photography.*

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365 Eggs

Stephen Jay Gould's "The Egg-a-Day Barrier" ("This View of Life," July 1986) notes that poultrymen have been unsuccessful in their attempts to achieve an egg a day from their stocks. This is true of those concerned with improving egg production in chickens and turkeys, but Gould and his readers should learn that a breeder in Ermelo, the Netherlands, did in fact have ducks which produced 365 eggs per laying year.

In 1963 I had the pleasure to visit with a Mr. Jensen in Ermelo and confirm the claim of "Each Day an Egg" on his company's stationery. An examination of production and pedigree records revealed that his Khaki Campbells indeed did reach the barrier and were producing 365 eggs per bird per laying year. They were obviously made of the right genetic stuff and received ideal management conditions and nutrition.

Khaki Cambells came about through crossbreeding Fawn and White Runners, Rouens and mallards. They were selected for egg production and not for meat production. White Pekin ducks of Long Island fame are meat birds that average approximately 130 eggs per year. Significant differences exist in performances among various breeds of ducks, but interestingly, Khaki Campbells, White Pekins, Runners, Rouens, and mallards all belong to the same genus-species, *Anas platyrhynchos*.

WILLIAM J. ASH
State University
Stony Brook, New York

Predicting Percentages

I enjoyed "The Panamanian Love Call" (June 1986), but get no information from the claim that the calling frequency was (depending upon the sample) 252 or 314 percent lower than its predicted value.

An innately positive quantity cannot be decreased by more than 100 percent. If the calling rate were 100 percent less t the prediction, it would be zero, and tha as low as it possibly can be. Perhaps I fessor Ryan meant that the predicti were 252 and 314 percent higher than measured values in the two cases so t the measurements were 71.5 and 75.8 p cent lower than the predictions.

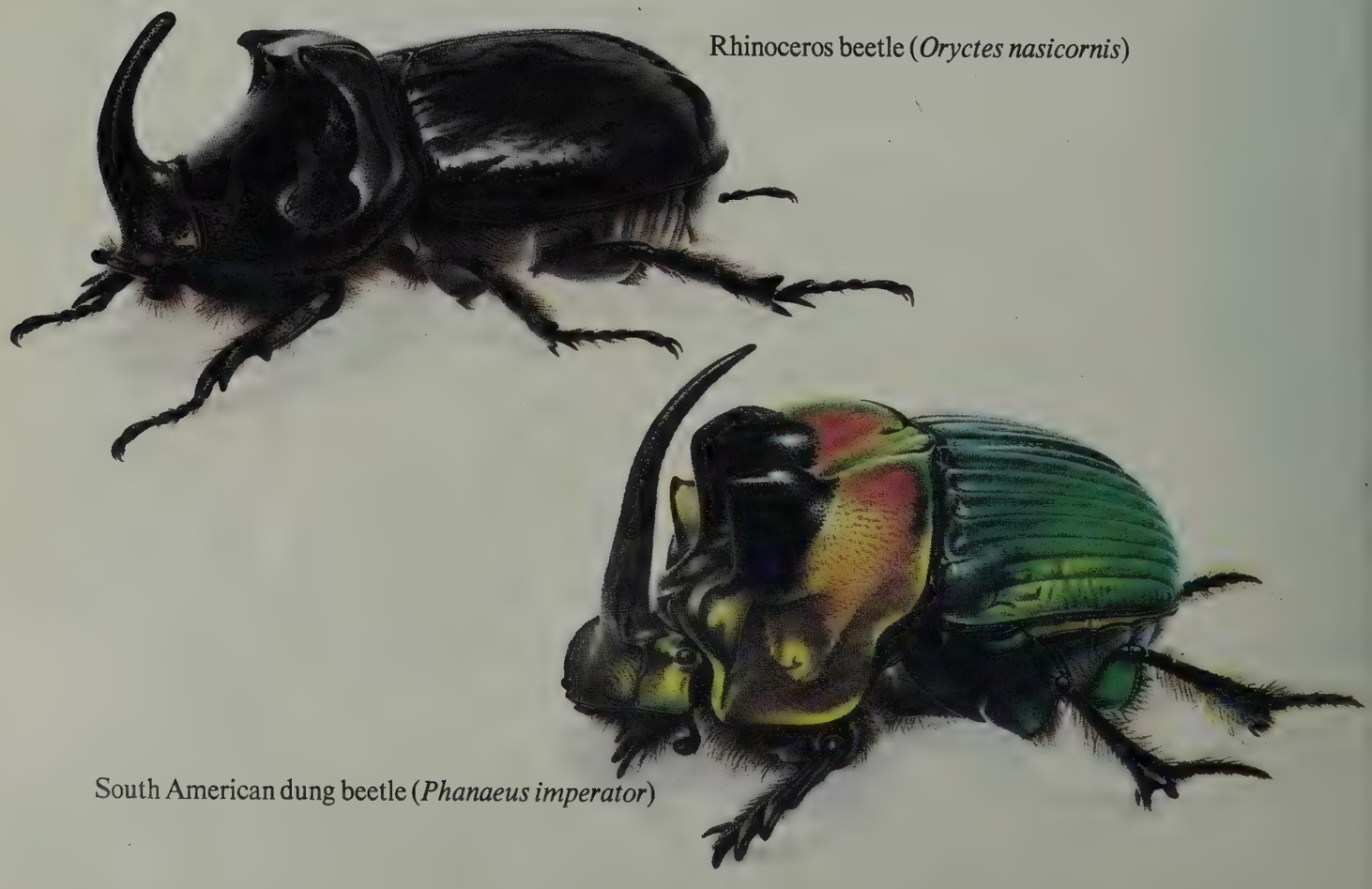
HAROLD SALW
Stevens Institute of Technol
Hoboken, New Jer

Correction

I am an insect collector from Leban Pennsylvania. I'm in 4-H Entomology a I'm nine years old. While reading y July edition, I found a mistake. In "On Dilemma of Horns," two picture capti were switched. *Phanaeus imperator* really shown on page 60.

I really enjoyed reading this artic One of my goals is a forked fungus bee

JEFFREY T. FR
Lebanon, Pennsylva



Rhinoceros beetle (*Oryctes nasicornis*)

South American dung beetle (*Phanaeus imperator*)

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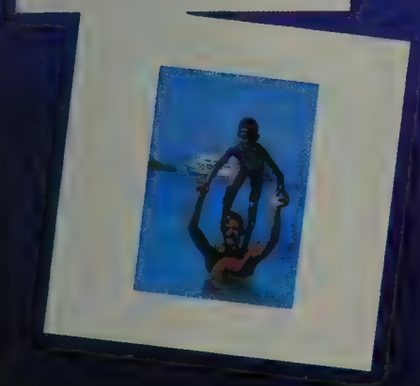

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Speaking "Indian" in Louisiana

Linguists trace the remnants of a Native American pidgin

by Emanuel J. Drechsel

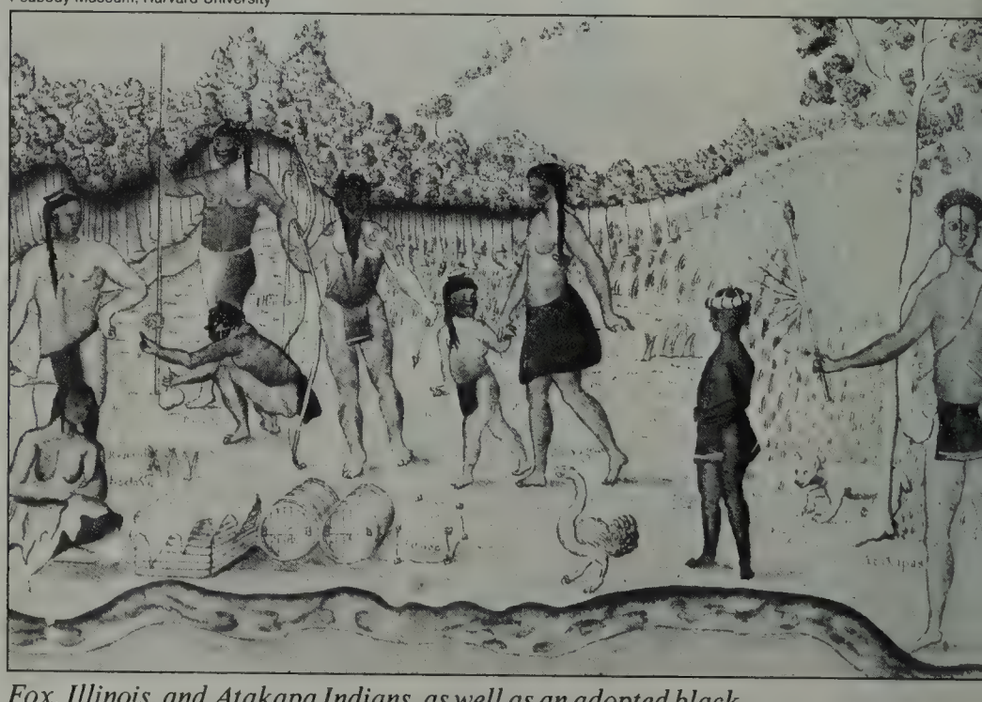
The word *bayou*, closely identified with the sluggish waters of Louisiana, bears the imprint of that state's French heritage, but in origin the word is not French at all. Instead it derives from *bayuk* (river, creek) in the language of the Choctaw Indians. Like some other words, and many place names current in and around the state, it entered general circulation by way of an international Indian medium, the Chickasaw-Choctaw trade language. This language was associated not only with the Chickasaws and Choctaws, two prominent and once strategically located Indian groups of Tennessee and Mississippi, but also extended to other, linguistically diverse native peoples all across colonial French Louisiana—which covered much of the central south—and beyond. Today it is most frequently referred to as Mobilian Jargon, after the Mobile Indians of southern Alabama (or perhaps after the French settlement of Mobile, which borrowed its name from its native neighbors). Many of the early European settlers simply called it "the Indian language."

More than 200 years ago, the Dutch-born Louisiana colonist Antoine Simon Le Page du Pratz, who considered Mobilian Jargon important enough to learn, asserted in his *Histoire de la Louisiane* that it had outlived its usefulness. French, he argued, had become the new language of the colony. His argument was reasonable, for as a colonial power France could and would impose her national tongue on the indigenous population and all immigrants. Few scholars subsequently questioned this conclusion, and until fairly recently modern anthropologists and linguists assumed that Mobilian Jargon was extinct.

In the late 1960s, however, the Native American craftsman Claude Medford, famous for continuing the tradition of weaving Southeastern Indian split-cane baskets, alerted linguists that some speakers of the international Indian medium survived. These older individuals in and around Native American communities of southwestern and central Louisiana, especially among the Coushattas and their neighbors, could recall words and single phrases of Mobilian Jargon. They had used the language as recently as the early 1950s, even though they knew French, and frequently English, as well as one two native languages. Thus, James Crawford, of the University of Geor and I have each been able to do lingui fieldwork with speakers of a language for all practical purposes had been writ off two centuries ago.

My attempts to collect informa from the small number of people who membered Mobilian Jargon did not ways go easily. When I first questio them in English or French, some sta that they did not know the language. B soon learned how to ask the same quest

Peabody Museum, Harvard University



Fox, Illinois, and Atakapa Indians, as well as an adopted black child, populate a 1735 drawing of life along the Mississippi. The woman at the lower left is enslaved, a common fate of Indian war captives. Mobilian Jargon, a native "international" language, was generally used in such settings.

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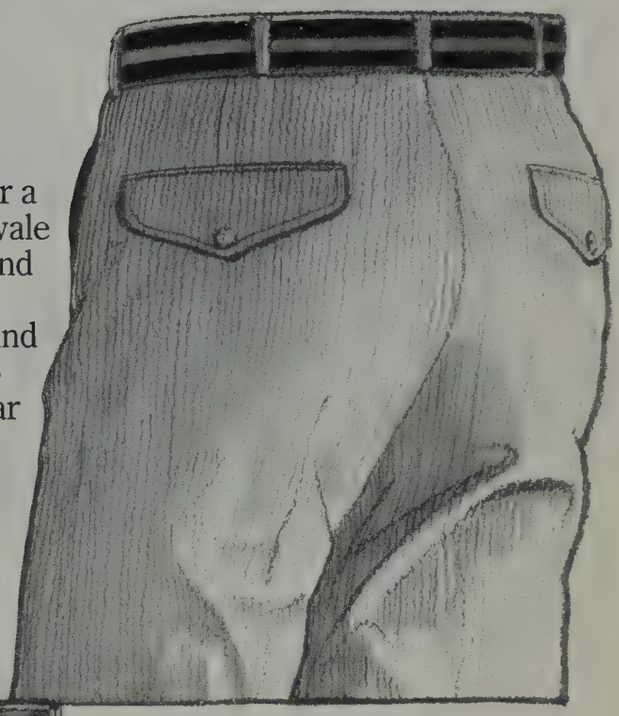

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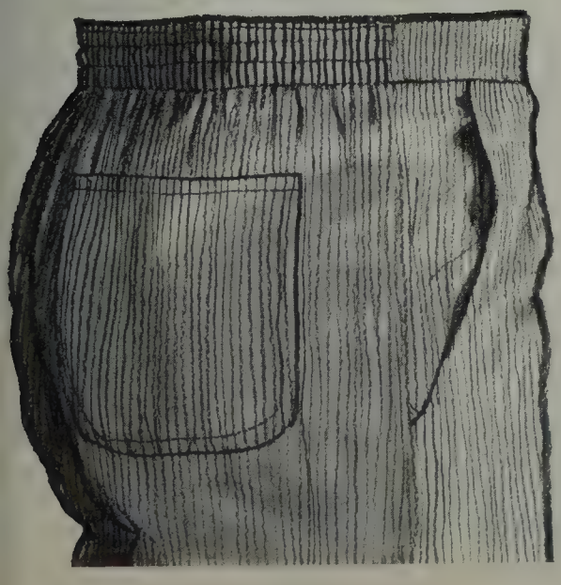

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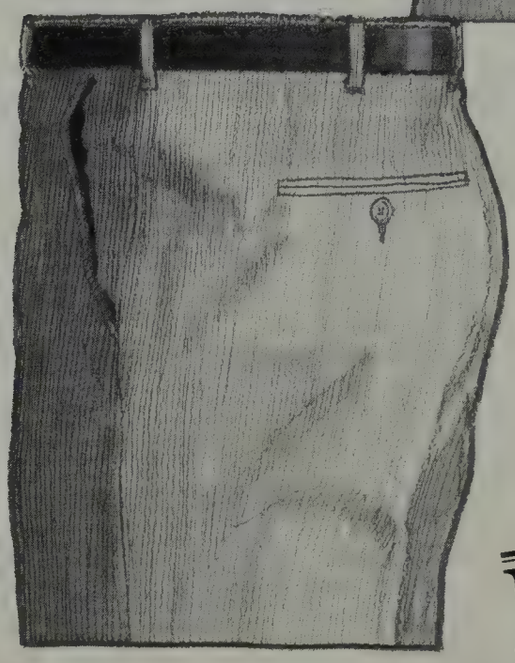

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Joe LeMonnier: Mississippian sites after James B. Griffin

Although its prehistoric origins are unknown, Mobilian Jargon may have arisen among the interconnected, agricultural chiefdoms belonging to what archeologists call the Mississippian complex, whose members spoke a number of different languages.

in the language itself: *Yama eshno anompole?* "Do you speak Mobilian Jargon?" When I addressed the same people in *yama*, as they knew it, they could rarely hide their surprise at a young non-Indian—and a foreigner at that (I am Swiss)—speaking the "old folks' language." The use of *yama*, appropriate in similar situations perhaps only a quarter century earlier, helped the language's last speakers to overcome their suspicion.

The people I contacted helped me trace others, until I had more than ten individuals to work with. Their revived memories brought forth additional vocabulary and even allowed us to re-create short conversations about the weather, daily events, and life in rural Louisiana. In the end, I gathered a vocabulary of some 600 words, substantial grammatical information, and many reminiscences. Some older Louisiana Indians recalled that they had used or heard Mobilian Jargon at intertribal dances, stickball games, and similar gatherings in the 1940s. On such occasions, they had even chanted joke songs in the language, which—in spite of their sometimes sarcastic contents—the audience had apparently received as comical.

Mobilian Jargon was a pidgin language, a linguistic compromise that evolved out of situations involving contact between speakers of several mutually unintelligible, often unrelated languages. By nature, a pidgin is always an auxiliary, second language to its speakers. Familiar examples such as Sabir (also known as Lingua Franca) of the Mediterranean, Petit-Nègre of the West African coast, and Neo-Melanesian of Papua New Guinea, sound like broken forms of their lexically related European languages, in these cases Romance languages of the Mediterranean, French, and English, respectively.

Pidgins that reflect the dominant influence of non-European languages and that Europeans adopted for use in their colonies arose infrequently or, at least, have been reported but rarely. One is Chinook Jargon, an American Indian pidgin of the Northwest Coast, once spoken by the region's linguistically diverse native peoples among themselves and in contact with immigrants from Europe and from the greater Pacific area (Hawaii, China, Russia, and elsewhere). Another comparable medium, although not spoken, was the Plains Indians' sign language.

As described by early European colonists, Mobilian Jargon showed little European influence—limited to single French loanwords—and at first impression, it sounded like a broken or simplified form of Choctaw or Chickasaw, two closely related members of the Muskogean language family. Unlike Choctaw, Chickasaw, or other Indian languages of the South, however, but like other pidgins, Mobilian Jargon had no endings or other affixes to express grammatical functions, such as subject, verb, and object. Grammatical function was exclusively determined by the word order: object-subject-verb. For example, the sentence, "I forg the song," translates into *Talowa en emehakse taha*, literally, "Song I forge PAST." For comparison, the same sen tence in Chickasaw proper would run a follows:

Talowa' am- alhkaniya -tok

song	prefix for the first-person singular subject, for verbs involving personal experience	forget	suffi for th pas tens

In this particular utterance, the word or der happens to be the same but is not th basic one for Chickasaw. In this and i most other Southeastern Indian lan guages, sentences generally follow the pa tern of subject-object-verb.

When I played tape recordings of th pidgin to speakers of Choctaw and Chick asaw in Mississippi and Oklahoma wh did not know Mobilian Jargon, they some times were able to interpret single word correctly, but could make little sense ou of sentences in what appeared to them as corrupted form of their language. In thei confusion they expressed utter disbelief i the existence of Mobilian Jargon. Some o them even thought that I was the victim o a hoax carefully staged by Indians an other people of Louisiana.

Archival research offers insights int Mobilian Jargon that modern fieldwor can no longer reveal, helping to comple ment our understanding of the pidgin' social history. Early documents describ Mobilian Jargon as a court, political, an public language, probably referring to th use of the pidgin at intertribal association and confederacies, which existed all ove the Southeast. From observations mad by the foremost ethnographer of South eastern Indians, John R. Swanton (187 1958), and because most of the last speak ers of Mobilian Jargon were married t spouses of different language back grounds, we may further infer that it fig ured in bilingual marriages involving a least one Indian spouse.

One of its many names, *yoka anomp* (servant, or slave, language), suggests tha in situations of Indian slavery, Mobilia Jargon was also used between the maste and the slaves, as well as among the latte themselves, who often must have spoke different languages. Southeastern Indian enslaved not only blacks but also member of enemy tribes. The traditional purpos of these slaves was not to provide chea labor to their masters; rather, they wer captives of war raids. If their owners di

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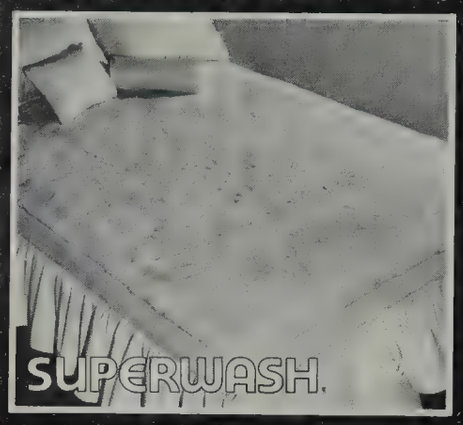

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not kill or slowly torture these "slaves" to death, they often assumed a petlike status. In many cases, the community eventually adopted them into their families, especially the women and children.

Already in early historic times, Louisiana's native population came to extend the use of Mobilian Jargon to their uninvited guests from Europe and Africa. Beginning with the first French explorations of the Mississippi Valley in the late seventeenth century, Christian missionaries

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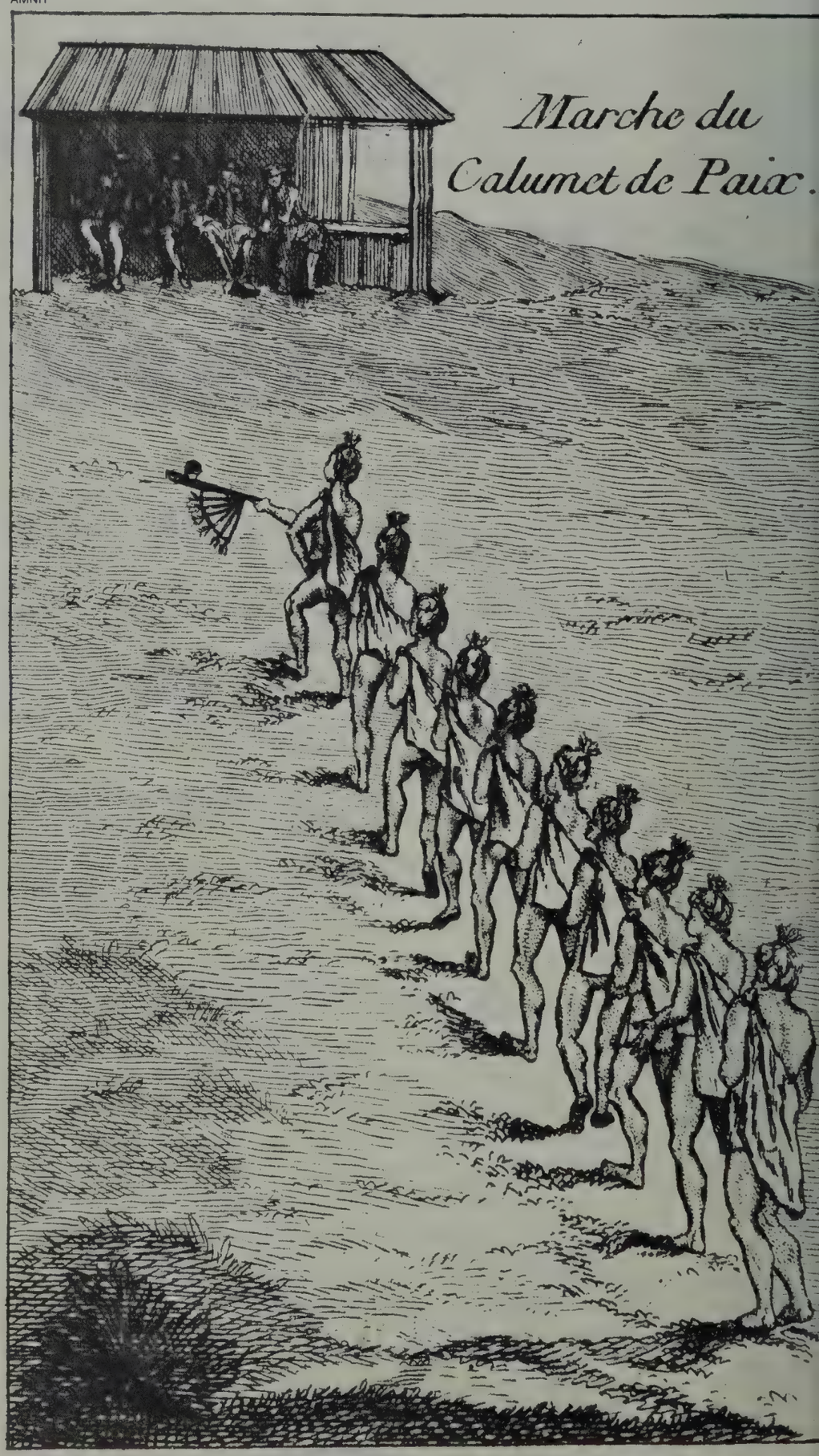

Louisiana Indians meet with Frenchmen in an illustration from Le Page du Pratz's 1758 Histoire de la Louisiane. *Mobilian Jargon was probably the language they had in common.*

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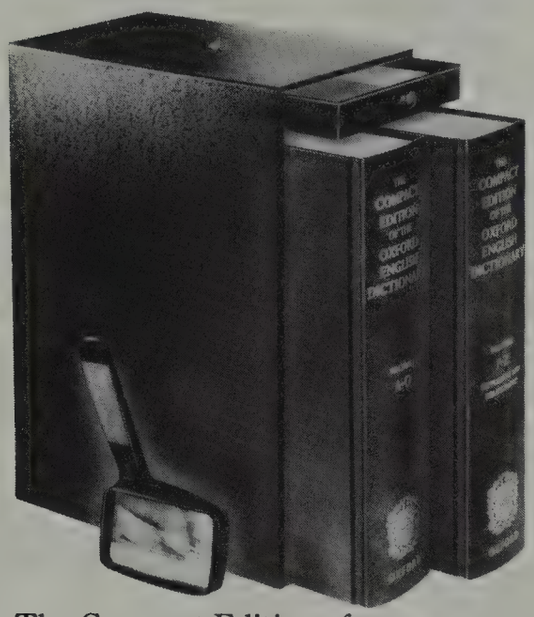

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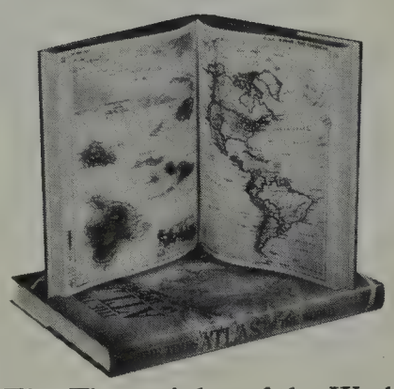

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adopted this medium as a means of converting the Louisiana Indians. Soon, French cabin boys and government cadets were being placed in native villages to learn "the Indian language," so that they could act as interpreters.

In its heyday during the eighteenth century, Mobilian Jargon came to range from northwestern Florida and eastern Alabama to eastern Texas, from the gulf coast to central Illinois and up along the Missouri River. The pidgin could be heard when southern Indians served as scouts for European explorers, as hunting and fishing guides, as slave hunters, or in the hide and fur trade. Later, in the nineteenth and early twentieth centuries, Mobilian Jargon continued as the medium for Indians engaged as sharecroppers, farm laborers, homesteaders, or workers in Louisiana's timber and oil industries. Anybody with substantial dealings among Louisiana Indians then took pains to acquire "their" language. On occasion, the pidgin even served between non-Indians, such as French and British traders.

In his book *The Mobilian Trade Language*, James M. Crawford argues that the pidgin arose following contact with Europeans, but this seems unlikely to me. The Indians of the area were among the first native peoples of North America to experience the far-reaching and devastating effects of European colonization, which took the forms of epidemic diseases, genocide, war, enslavement, theft, and dislocation. Under the circumstances, the Europeans would have been more likely to impose their own languages rather than adopt some newly evolving, native pidgin. That they found it more convenient to use Mobilian Jargon suggests that it was already well established and widespread in precontact times.

The longevity and pervasiveness of Mobilian Jargon are surprising, however. Undoubtedly, the linguistic complexity of Louisiana contributed to the survival of the pidgin into this century. By estimate, people in the larger Mobilian Jargon community once spoke a minimum of thirty Native American languages. Some were isolates (languages without obvious, close relatives); the rest belonged to at least five different language families—Muskogean, Caddoan, Siouan, Algonquian, and Athapaskan—each as diverse as any of the major European language families, such as the Romance. In the state of Louisiana alone, about ten Southeastern Indian languages survived throughout the nineteenth century and as many as five until the 1950s. Today at least Coushatta and Choctaw are still spoken. In addition, the diversity of the immigrants' languages—which included French, English, and pidginized or creolized versions thereof; Spanish; German; and perhaps African languages—may have strengthened the interlingual medium.

Some Words in Mobilian Jargon and Their Derivation

Mobilian Jargon	Translation	Source
papos(h)	*baby*	Some Algonquian language of northeastern North America, such as Narragansett
chanalle lashpa	*car*	Choctaw, literally "wheel hot"
kato	*cat*	Spanish *gato*
kafe	*coffee*	Spanish or French *café*
wak(a)	*cow*	Spanish *vaca*
neshken	*eye*	Some Algonquian language of northeastern North America, such as Ojibwa or Delaware
shlashlo	*fish*	Alabama or Coushatta
(a)chukma	*good*	Choctaw or Chickasaw
shapo	*hat*	French *chapeau*
oke lowak	*liquor*	Alabama or Coushatta "water" and Choctaw "fire"
s(h)onak	*money*	Some Algonquian language of the Great Lakes area, such as Ojibwa
-(e)ksho	*not*	Choctaw or Chickasaw
shawe	*raccoon*	Choctaw or Chickasaw
anompole	*to speak*	Choctaw or Chickasaw
toksale	*to work*	Choctaw or Chickasaw

Another reason for the continued use of Mobilian Jargon into modern times lies in the favorable attitudes people have held toward it. Pidgins generally have enjoyed little or no prestige around the world: colonists have looked down upon these contact languages as the native peoples' poor attempts at learning the "standard" languages. The frequent association of pidgins with slavery has not helped to improve their status either. But to the best of my knowledge, those who spoke Mobilian Jargon or observed its use did not attach any negative values to it. The surviving Indian speakers I interviewed regarded it as nobody's language and thus a neutral, impartial medium, a welcome tool in the linguistic and social diversity of Louisiana. On the other hand, the remaining black and white speakers of Mobilian Jargon, who were not aware of its pidginized nature, took pride in their knowledge of "the Indian language."

I believe that the most important reason for the extended survival of Mobilian Jargon, however, was that it served—in apparent contradiction to its function as a contact medium—as a linguistic and social buffer for Louisiana and other southern Indians against non-Indian intruders. This was not its original function, for French explorers and colonists of the eighteenth century (such as Le Page du Pratz) evidently encountered little difficulty in learning about the true Indian languages, and they recognized the pidgin's function as an intertribal medium. But later historical documents reveal some of this buffer function. In 1802, for example, Martin Duralde, commander of the Atakapa Post near present-day Opelousas, explained his lack of Atakapa and Coushatta vocabularies with the observation that the Indians spoke to the Europeans only in Mobilian Jargon. A missionary family made a similar discovery early in this century, as described in 1968 by Aline Rothe in her book *Kalita's People: A History of the Alabama-Coushatta Indians of Texas.*

> The true tribal language is spoken only in the privacy of the Indians' homes. Where white people can hear them speak, they use a "trade" dialect, a common language used by a number of tribes for purposes of trade and communication. The Reverend and Mrs. Chambers did not know there were two dialects used until their daughter Dorothy was six years old. She had learned to speak the language of the Indians [that is, Alabama or Coushatta], and one day in Livingston, the Chambers family met a man who had been closely associated with the Alabama and Coushatta for several years and was said to speak their language. The man and Dorothy tried to talk to each other in the Indians' native tongue, but they could not understand each other. Dorothy's

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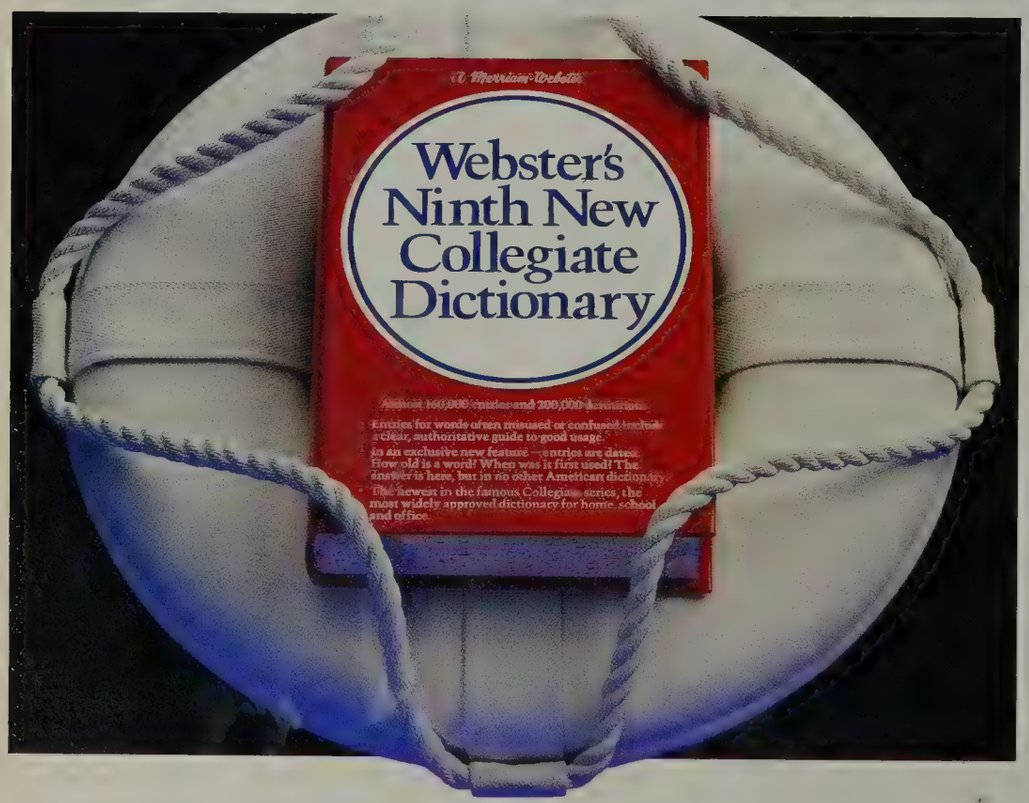
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parents were disappointed, for they had been under the impression that she could speak the Indians' language. But they soon discovered that their daughter, who had been received into the Indians' homes, could speak their real language, whereas the man with whom she had tried to converse knew only their "trade" dialect.

A child like Dorothy apparently did not threaten the Alabamas and Coushattas, and thus they felt no need to conceal their native languages from her.

My own fieldwork experiences with Louisiana Indians matched those of Duralde and the Chambers family. Those I interviewed took much pleasure reminiscing in and about Mobilian Jargon, as well as teaching it to me. Despite my anthropological inquisitiveness, I evidently did not invade their personal or private spheres, since the international language was the perfectly appropriate medium between them and outsiders like me. As nobody's language, it was—so to speak—public property. Yet when I inquired about the Indians' own languages, they were hesitant to answer my questions until they had an opportunity to get to know me better. Asked why they were so reticent, they explained that their languages were too difficult for non-Indians, who were only capable of learning the pidgin. But the true reason, I believe, was their wish to keep their native languages to themselves.

There were good historical reasons for Mobilian Jargon to have developed such a buffer function. With the Louisiana Purchase in 1803, the United States acquired a vast territory that extended far beyond the boundaries of the modern state of Louisiana, all the way to the Rocky Mountains. Shortly thereafter, hordes of settlers began crossing the Mississippi, creating conflicts between themselves and the Indians, as well as between Indian groups, over the limited resources. In addition, the American custom of lumping all nonwhite peoples, irrespective of their ethnic origin, into the category of "colored folks" threatened to increase the enslavement of Louisiana and other southern Indians, who had received greater recognition and independence under French and Spanish rule. Short of fighting the encroaching settlers, Louisiana Indians had little choice but to emigrate to Indian Territory (now Oklahoma) or to withdraw into marginal and inaccessible areas, such as the swamps, bayou country, and woods of Louisiana. Many Louisiana Indians arrived too late in Oklahoma to find a new home, so they chose the latter alternative, and ended up hiding in their own backyards.

By restricting their native languages in communications with non-Indians and in-

ting on the pidgin as the proper me-
ım, Louisiana Indians could limit the
tsiders' access to their endangered
ɔrld. At the same time, by allowing
ıites and blacks to believe that in acquir-
ɜ Mobilian Jargon they had learned the
e and only Indian language, Louisiana
dians could affirm their identity and
ųs reduce the chance of being mistaken
"colored." Not surprisingly, those Loui-
ına Indians who used the pidgin the
ngest belonged to the culturally most
nservative Native American communi-
ɔs in the southeastern United States.

Given the resilience of Mobilian Jargon
historic times, I am tempted to specu-
te about the role the language may have
ayed in prehistory. The Southeast was
ɔme to the most elaborate pre-Colum-
an sociopolitical organization north of
lexico. Known to archeologists as the
lississippian complex, it extended along
ıe Mississippi River and its tributaries
ɔm about A.D. 850 until the entry of the
panish and French explorers into the
ɔuth. Leaving its mark in the form of
rge earthen mounds, this prehistoric
ɔmplex consisted of agriculturally based
rge chiefdoms interconnected by exten-
ve trade, political alliances, and shared
aditions. The cultural uniformity of the
outheast, however, contrasted with its
nguistic diversity. Through the practices
f war and slavery, along with the forma-
on of confederacies, the Mississippian
ɔmplex must have incorporated peoples
ɔeaking various mutually unintelligible
nd even unrelated languages. Under
ıose circumstances, a pidgin would have
een extremely useful, serving in effect as
national language.

I find it suggestive that the historic dis-
ribution of Mobilian Jargon closely
ıatches the distribution of archeological
ites known for the prehistoric culture.
Whether Mobilian Jargon was actually
poken by people belonging to the Missis-
ippian complex, however, is something
ve will never know for sure. And in any
ase, the language may have been very
lifferent in the past. We cannot even be
ertain that the vocabulary of prehistoric
Mobilian Jargon consisted primarily of
vords from Choctaw, Chickasaw, or some
ɔther Muskogean language, since the
ɔocabulary of a pidgin can alter radically
ɔver time. But I like to think that words
ike *bayou* provide a historical link to a
ɔng-gone tradition, one usually known
ɔnly by mounds, artifacts, and bones.

Emanuel J. Drechsel, who is currently on leave in Hawaii, is associate professor of anthropology at the University of Oklahoma.

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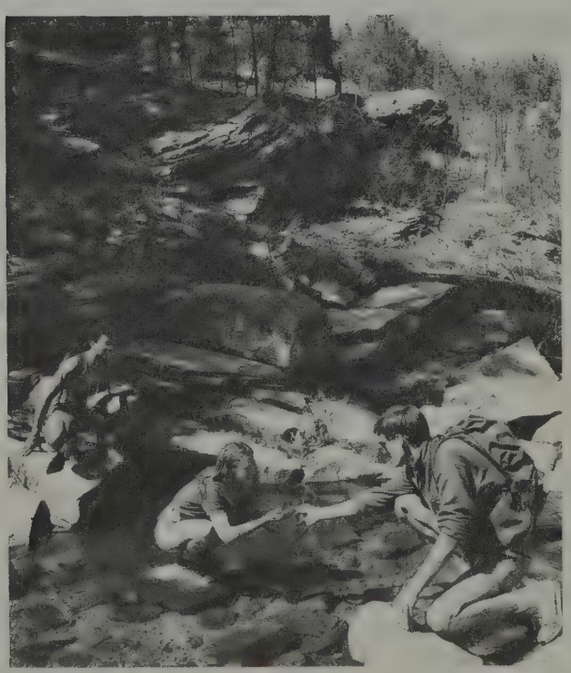

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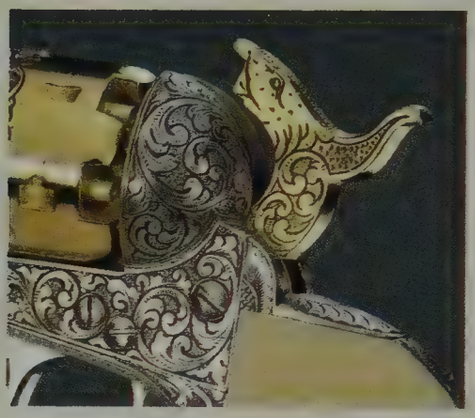

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The Archaeopteryx Flap

Cardboard histories can be deceptive and destructive

by Stephen Jay Gould

We reserve our special scorn for the little and most immediate errors—the person who doesn't know right from left or arse from elbow. We also enjoy high drama rooted in tiny lapses of memory about the basic structure of our world and ourselves—consider Phileas Fogg, who almost lost his bet, convinced that he had used one more than his allotted eighty days to circle the globe because he had forgotten about the fundamental concept now embodied by the international date line. Thus, in 1868, Thomas Henry Huxley approached the task of further dismantling his greatest scientific enemy with special relish, for Richard Owen had described the world's most famous fossil upside down.

Archaeopteryx, literally the ancient wing, lies spread out on a bedding plane of the celebrated lithographic limestone of Solnhofen, in Bavaria, a late Jurassic deposit from the midst of the dinosaur's reign. This first bird, with its exquisite and perfectly formed feathers attached to a basically reptilian skeleton, had been bought by the British Museum in 1862 (a year after its discovery) from Dr. Karl Häberlein, district medical officer of Pappenheim and driver of hard bargains. For the princely sum of 700 pounds (quickly put to use as the dowry for Dr. Häberlein's daughter), the museum traded nearly two years of disposable income to obtain 1,703 specimens from Solnhofen. It was a fine collection to be sure, but all paled to insignificance before the single reason for the purchase—the only specimen of an apparent intermediate between two major groups of organisms, a key and contentious creature in a scientific world still trying to sort out the impact of Darwin's theory, published just three years earlier. (To this day, we have recovered but five other examples of *Archaeopteryx:* a partial skeleton found in 1855 but then misidentified as a pterodactyl, or flying reptile; a single feather also known in 1862; the famous East Berlin fossil, the only other adequate specimen, found in 1877; and two discovered during the 1950s. Häberlein received his booty for a prize then unique.)

Richard Owen, director of the museum, had lobbied hard for the purchase and won the right to describe the precious specimen ("On the *Archaeopteryx* of von Meyer, with a description of the fossil remains of a long-tailed species, from the Lithographic Slate of Solenhofen," *Philosophical Transactions of the Royal Society of London*, 1863, pages 33–47). Owen interpreted the fossil as lying belly up on the main slab.

No animosity in Victorian science ran deeper or longer than the feud of Owen with Thomas Henry Huxley. Their debate is usually misconstrued as a chapter in the fight between evolution and creation—an entirely false interpretation crucial to the ludicrous error exposed in this column. Although their argument did center upon large generalities in biological theory, Huxley was a brilliant debater who understood that the sweetest fruits of victory lay in ridiculing an opponent for incompetence in the description of concrete and obvious things, not in brilliant flights of oratory about cosmic verities. He had skewered Owen eight years previously in the great "hippocampus debate," when he proved, with anatomical flesh and blood for all the world to see, that both humans and apes possessed a hippocampus minor in their brains—and that the supposed absence of such a structure in apes, as Owen had held, could not mark an unbridgeable gap between bestiality and consciousness.

Huxley now prepared to gloat again, for he had noticed that *Archaeopteryx* really lay belly down on the famous slab and that Owen had therefore reversed everything—all his described rights were actual lefts and vice versa. (In fairness to Owen, the twisted specimen is not easy to resolve, and one prominent bone—the furcula ["wishbone" to us, but "merrythought" to them in a different designation for the same custom]—is detached from the rest of the specimen and turned to lie ventral, or belly side up, the source of Owen's error). In smug understatement, and with venom scarcely concealed, Huxley moved in for a second kill, scorning even to mention Owen's name except in a footnote ("Remarks upon *Archaeopteryx lithographica*," *Proceedings of the Royal Society of London*, 1868, pages 243–48):

> It is obviously impossible to compare the bones of one animal satisfactorily with those of another, unless it is clearly settled that such is the dorsal and such the ventral aspect of a vertebra, and that such a bone of the limb-arches, or limbs, belongs to the left, and such another to the right side.

Score another big win for Huxley, but the fullness of history often drowns an immediate triumph in irony. Although he muffed his description, we now realize that Owen was right, and Huxley wrong, in the central aspect of their general interpretations.

We now regard *Archaeopteryx* as an evolutionary intermediate, a transitional form between reptiles and birds. And so did Owen, who was not a creationist, but who hated Darwin's explanation for their shared acceptance of evolution (more on this later). Owen got the particular sequence wrong; he thought that *Archaeopteryx* had developed from the reptilian fliers known as pterosaurs, particularly from long-tailed *Rhamphorhynchus*. But he stoutly defended the transitional status of *Archaeopteryx* and castigated unconvinced creationists for their implausible alternative of miraculous manufacture, while strongly denying that evolution leads to impiety:

> But whence the dove? Are we then, I will not say driven, but rather guided, to the old belief that the winged bird was "created" in the sense of being miraculously made, at once, out of dust .... Or, is a belief in a dove's coming to be through the operation of a secondary law still legitimate and ger-

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main [*sic*] to our truth-seeking faculties? Not necessarily relegating an honest inquirer to the bottomless pit of atheism. [From an 1875 monograph on the dinosaur *Omosaurus armatus*; "secondary causes," in Owen's terminology, are ordinary laws of nature, evolution in this case, rather than direct productions of God, the first, or primary, cause.]

Owen then argues that we do not yet know the general causes of evolutionary transformation but can nonetheless identify the proper sequence of long-tailed pterosaur to *Archaeopteryx*, the first bird:

> Neither has the biologist been able, as yet, to explain how the *Ramphorhynchus* [*sic*] became transmuted into the *Archaeopteryx* . . . . Every bone in the bird was antecedently present in the framework of the Pterodactyle . . . . Some pterodactyles had long tails and all had toothed jaws. A bird of the oolitic period [Owen here identifies *Archaeopteryx* in a footnote] combined a long tail of many vertebrae with true avian wings.

Huxley, on the other hand, refused to view *Archaeopteryx* as a transitional form, interpreting it instead as "all bird," though the most primitive version of its class. (This, to pile irony upon irony, is the position of modern creationists who must flatly deny the existence of all transitional forms. Obviously, creationist Duane Gish and Darwin's bulldog maintained this area of superficial agreement for diametrically opposite motives.) This first bird, interpreted as transitional, did not fit Huxley's view of avian origins—so he depicted *Archaeopteryx* as a side branch at the base of the family tree of birds. Huxley—and he was right in this—argued that flying birds had evolved from small running dinosaurs but (and here he was wrong) long before *Archaeopteryx* and by the very different, intermediary route of flightless ground birds similar to modern ratites (ostriches and their kin). Thus, our modern view is an amalgam of Huxley and Owen. We believe that Huxley was right about dinosaurian origins for birds but wrong about timing (too early) and intermediary forms. Owen was wrong in identifying pterosaurs as reptilian ancestors but right about timing and, particularly, about the transitional status of *Archaeopteryx*.

So why have I dredged up this tidbit of forgotten history? If you have been reading the newspapers during the last several months, I suspect you will already know. Fred Hoyle, eminent cosmologist of years past and more recent supporter of uncommon causes, has charged that the British Museum specimen of *Archaeopteryx* (and by implication all others with feathers) is a forgery manufactured from modern feathers pressed into a layer of artificial cement painted atop the genuine skeleton of a small dinosaur. Outraged as I was by the ignorant presentation of Hoyle and his colleagues, and by the poor quality of their arguments, I had decided nonetheless to bypass the incident in this forum for two reasons (despite numerous requests for my views): first, monthly magazines with quarterly lead times cannot resolve hot issues that break and close at the daily rhythm of newspapers; second, I regarded Hoyle's charge as so devoid of intellectual content that I couldn't find a handle for any interesting or general point worth discussing. But then, in their latest of several articles in the *British Journal of Photography*, Hoyle and company took a new tack and supplemented their failing tale with the major, previously missing piece desperately needed to form a complete case. Heretofore, they had avoided the issue of motive—whodunit and why—that any claim for such spectacular fraud must include.

Now, they maneuvered to fill this gap and centered their speculations on Richard Owen, inventing a fabulous tale that could only wash if Owen were a creationist. Since nothing offends me more than cardboard history trumpeted for base motives, I had my handle. Scores of popular articles have treated Hoyle's charges about the slab in detail, but no one (that I have read) has criticized his speculations about Richard Owen's motive. The explosion of Hoyle's ill-considered speculation about "why" stands prior to his poor arguments for "how"—but few paleontologists recognize the truly rotten core in Hoyle's argument.

I will not, as I said, dwell on technical details of Hoyle's charge about the fossil itself but must provide this outline to set context: Solnhofen is the most famous of our rare and precious "windows," provided by occasional preservation of soft parts, into the true diversity of ancient life. Solnhofen fossils reveal astounding detail, from thin membranes of jellyfish to minute hairs on the appendages of arthropods. Thus, sediments could surely preserve feathers if any creatures sported them at the time; no one disputes this.

The authenticity of the skeleton itself has also not been questioned. Hoyle's beef lies with the feathers. He and his colleagues argue that the forger spread a layer of cement upon the two surfaces of the split slab, mixing comminuted limestone from the quarry (to avoid obvious differences from the rock itself) with a binder. Modern feathers were then pressed into the wet cement to form the famous impressions.

Alan Charig, curator of fossil reptiles and birds at the British Museum, and four colleagues (Frank Greenaway, Angela C. Milner, Cyril A. Walker, and Peter J. Whybrow) have recently disproved Hoyle's cement theory ("*Archaeopteryx* Is Not a Forgery," *Science*, volume 232, May 2, 1986, pages 622–26). Charig and company's arguments are devastating in their accumulated impact, but two seem particularly decisive to me. The fossil was originally revealed by splitting a block of Solnhofen stone in two along a bedding plane. Most bones and the best feather impressions lie on one block (called the slab); the other block (called the counterslab) also sports an impression of the animal. If a layer of forger's cement now separates slab and counterslab, they will not match in detail.

Basically, Charig and company have proved the exquisite fit of slab with counterslab. They point first to hairline cracks filled with mineral deposits (quite common in such sediments and produced by a variety of causes in the hardening of muds to rock—cracking, expansion, percolation, for example). These cracks extend through the rock and could not have been made by any forger spreading cement on the surfaces. Yet the network of slab cracks runs right to the surface and continues, with perfect fit, to an extension of the same network on the counterslab. No layer, artificial or otherwise, lies atop slab or counterslab. Secondly, dendrites (delicate, inorganic treelike patterns formed by precipitation of manganese dioxide) cover parts of the surface of both slab and counterslab; some lie directly atop feather impressions. Charig and company photographed these dendrites on the counterslab, printed the negative backward, and then compared the photograph with corresponding dendrites on the slab. They match exactly to the finest branchlet of the delicate arborescence. Nothing separates slab from counterslab. The dendrites must have lain on the bedding plane before the rock was split.

This is evidence enough, but I might throw in my two cents on three additional points that seem equally decisive.

1. How was the forger supposed to introduce birdlike features into the skeleton? He might press feathers into cement, but where would he get an appropriate wishbone, a retroverted pubis (pelvis bone pointing in an avian rather than reptilian direction), and a perching foot? These bones look like, and attach to, all the others. Predominantly reptilian, the skeleton also displays several avian features.

2. Conspiracy theories easily fall victim to their own complexity. I can see one

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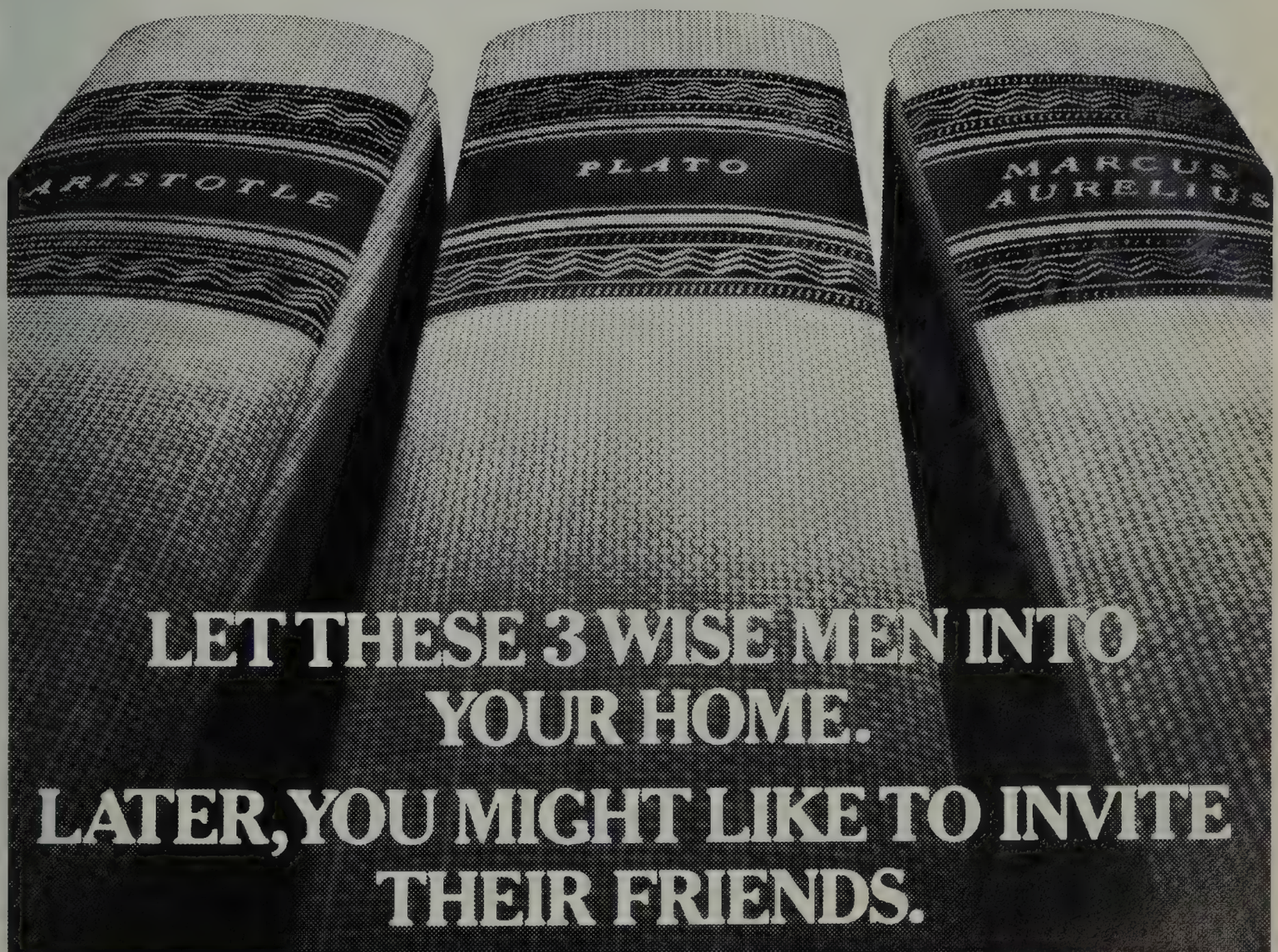

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greedy man pressing some feathers in 1861. But was he still working in 1877, when the Berlin specimen emerged? And did he pass the trick to distant descendants for later repetition in the 1950s? (Hoyle has claimed poor and indecisive preservation of feathers on the two 1950s specimens, a contention vigorously denied by Charig.)

3. Hoyle and colleagues reveal some astounding carelessness in their descriptions. Their first article states that the tail sports but a single feather—"a large and conspicuous tail feather that adorns the creature with ceremonial splendor." But everyone has known right from the start that the tail vertebrae are covered with a large series of separate feathers, orderly arrayed two to a vertebra. Even the amateur collector Häberlein noted this arrangement in a letter describing his prize to British Museum authorities, writing about "der Schwanz, welcher auf beiden Seiten und um die Spitze mit ausgebreitenen Federn besetzt ist" (the tail, which possesses feathers spread out on both sides and at the tip). Moreover, as Owen first noted in his 1863 article, the tail feathers are clearly attached by ligaments to the vertebrae. Could a forger manufacture ligaments to attach each separate feather directly to a vertebra in such clear order?

But why even bother with such an elaborate theory for forgery if you don't have a motive? Hoyle has latched on to conventional cardboard history about Richard Owen to supply this primary prerequisite.

The cardboard story, or Western movie approach to history, wallows in our lamentable tendency to dichotomize complex issues and to reduce all subtle stories to moralisms about goodies and baddies. Evolution was the great watershed of mid-nineteenth-century biology. In the cardboard version the actors were either fer or agin it—two camps absolutely opposed. The two camps need standard-bearers, symbols to play their appropriate moral roles in a fable that rapes history for modern messages fed as pap to students.

Thus, in cardboard history, evolution divides sheep from goats, and Darwin himself serves as the criterion for separation. Huxley, of course, sits at the right hand of rectitude. But who gets to play the infidel King Saladin in this particular crusade? No one in England quite fits the bill, but someone must serve. Cardboard history has therefore drafted Richard Owen for this role, for several reasons, all bad (as we shall see). Owen was, by all accounts, a most unpleasant man who picked a long and vigorous fight with Darwin. Moreover, in the greatest single myth of scientific hagiography, Owen played a villainous role in the greatest victory of light over ignorance—Huxley's demolition of Samuel Wilberforce in 1860—for Owen was seen whispering into the good Bishop's ear, supposedly priming him with choice anti-Darwinian arguments.

In his theory of motive, Hoyle contends that someone in Bavaria, perhaps Häberlein himself, pressed feathers into the cement for simple economic purpose. Owen, as a brilliant anatomist and director of the British Museum, must have realized that the specimen was a fraud, but purchased it as part of an elaborate plot to undermine Darwin and discredit evolution. Hoyle and colleagues write:

> This [Owen's desire to purchase at great cost] makes no sense at all if Owen thought the fossil to be genuine, for he would then have been helping Darwin to a marked degree by adding support to the Darwinian theory. Owen's apparent generosity only makes sense if he were laying a trap .... Richard Owen supported Bishop Samuel Wilberforce on the occasion of Wilberforce's debate with Huxley at the famous Oxford meeting of the British Association in June 1860. It is easy to imagine that, smarting later under the majority view that Huxley came off best in the debate [see my column of May 1986 on why the debate was, at best, a confusing draw], and opposing Darwin almost to the point of paranoia, Owen laid a trap for them both—by providing the Darwinians with a creature well-fitted to their point of view, but fraudulently executed.

So single-minded was Owen, as champion of his side in the great dichotomy, that he willingly risked injury to his own reputation, and to the great Museum that he headed, in order to slay the greater foe:

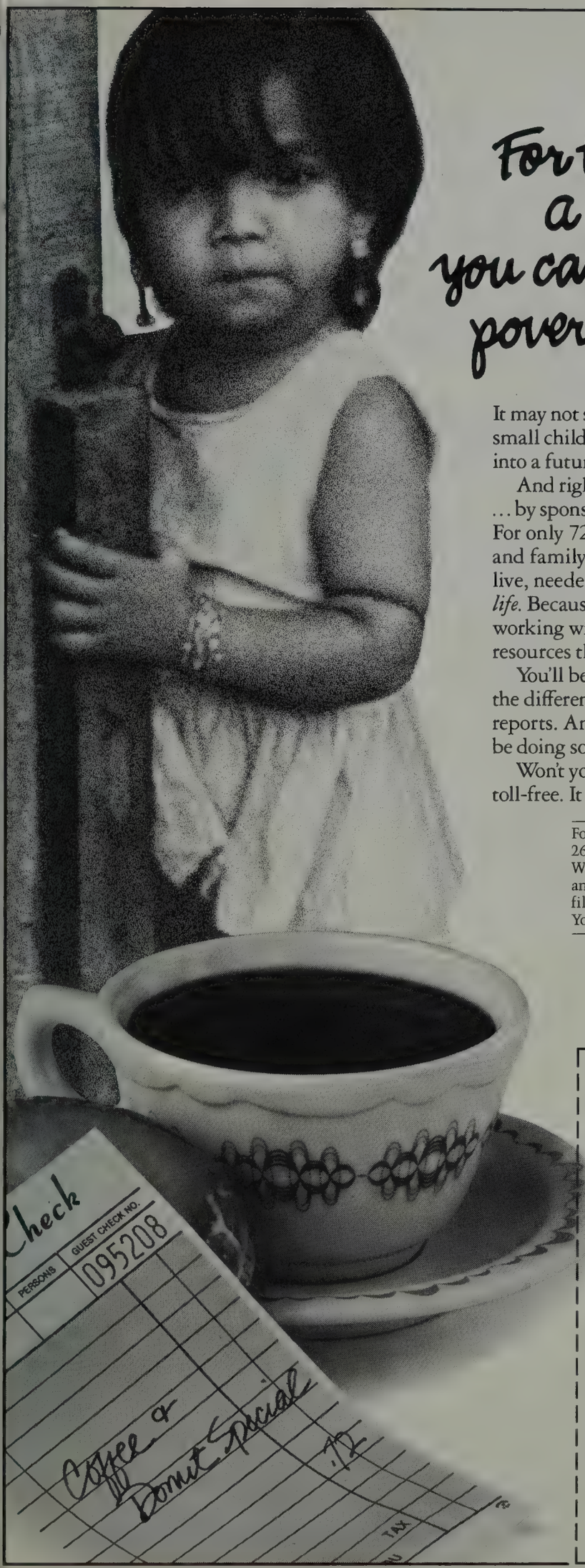
> Taken in a modern light it might be thought that Owen would have lost reputation through the intemperate purchase of a forgery. But in the social climate of 1862 the downing of Huxley and Darwin would have brought Owen more reputation in what were considered respectable circles than he would have lost elsewhere.

This fantastic tale rests upon two utterly false premises. First, we must believe that *Archaeopteryx* somehow provided crucial evidence for Darwin's particular views about evolution—support, presumably, for the theory of natural selection itself. But it didn't. How could one specimen speak for any theory of evolutionary process? Populations evolve, not individuals. While *Archaeopteryx* pleased Darwin, he made no special point about it in his writings. *Archaeopteryx*, as a precious transitional form, does speak well for the idea of evolution itself, but it does not tout one theory over another. This single fossil would delight the supporters of almost any conceivable notion about evolutionary mechanisms—Darwinians as well as Lamarckians, vitalists as well as mechanists.

Second, we must believe that Owen was the chief foe of evolution, for while *Archaeopteryx* supports no particular idea of evolutionary mechanism, this fossil surely argues for evolution itself—and its exposure as a fraud might embarrass Darwin's larger cause. But now we run headlong into the idiocies of cardboard history. In the cardboard version, Darwin is evolution; everything centers around him and natural selection. You are either entirely with Darwin and an evolutionist or against him and a creationist. But evolution, as the biggest idea that biology ever promoted, did not exist as one prepackaged orthodoxy. England in 1860 boasted hundreds of evolutionists, struggling with at least a dozen major theories for how evolution worked.

And so we come to the one-liner that epitomizes this essay and sinks Hoyle's conjecture: Owen—although a fierce anti-Darwinian—was also an evolutionist. Moreover, as I demonstrated by quotation in the first part of this essay, he used *Archaeopteryx*, actively and explicitly, to support both his own view of evolution and his particular ideas about lineages in the phylogeny of birds. Rather than hating all that a feathered *Archaeopteryx* would represent, and buying a fraud with which to sink Darwin, this bird fit splendidly with Owen's central theories, and he welcomed and used its discovery as joyfully as any scientist.

A further study of Owen's life and ideas should drive the final nails into the coffin that Hoyle has constructed for himself. Richard Owen was fiercely dedicated to the British Museum of Natural History. He became its superintendent (director) in 1856, when the museum still resided in Bloomsbury with its more celebrated collections in history (Magna Carta) and archeology (Rosetta stone and Elgin marbles). Owen dreamed of a separate building for the natural history collection. In 1859, he submitted a forceful report to the trustees, pleading the cause of a new and independent housing. He persuaded his friend Gladstone to introduce an enabling bill into Parliament, a move that succeeded after several failures. Work began in 1871, and the South Kensington building, perhaps the greatest legacy of Victorian public architecture, opened in 1884. (Don't miss it, especially in its freshly cleaned state, if you ever visit London.) In the same year, Owen, who had continued as superintendent to see his



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dream established, finally retired at age eighty and received a knighthood from Queen Victoria. Now, seriously Mr. Hoyle, do you really think that Owen would have compromised his dream with a phony bird, especially at such a crucial time so early in his campaign for a separate building?

I am no lover of Richard Owen; almost no one is. By all accounts, he was a remarkably unpleasant man—a social snob who courted people he needed, worked endlessly for personal aggrandizement, and picked fights to undermine anyone who stood in his way or just dared to disagree with him. Darwin, unwittingly, ran headlong into his wrath not, as the cardboard account holds, because Owen loathed evolution but because he despised Darwin's mechanistic and materialistic account of natural selection, opting instead for a romantic version based on innate powers of organisms and their prefixed laws of change.

Darwin and Owen began on good terms. Darwin sought out Owen to describe the fossil vertebrates that Darwin had collected on the *Beagle*, and Owen is the author of *Toxodon* and most of Darwin's other famous fossils. But many years later, Owen chose to regard natural selection as a perverse usurpation of his own preeminence in zoological ideas and turned viciously against Darwin. In his *Autobiography*, Darwin lamented with astute judgment:

> I often saw Owen whilst living in London, and admired him greatly, but was never able to understand his character, and never became intimate with him. After the publication of the *Origin of Species*, he became my bitter enemy, not owing to any quarrel between us, but as far as I could judge out of jealousy at its success.

Owen was no enemy of evolution, the basic idea that organisms connect by ties of genealogy. He could be frustratingly vague (especially when courting favor in conservative circles), and his labored style of writing didn't aid clarity, but we cannot doubt that he supported some form of evolutionary theory, at least after the 1840s. He usually expressed his belief (as my opening quotations demonstrate) with the standard argument of religious scientists in the Cartesian tradition: God made the world and then let it run without further interference according to laws of nature ("secondary causes" in Owen's terminology) that he established at the outset. Evolution ranks prominently among these secondary causes, or laws of nature. Owen used exactly the same simile favored by modern evolutionists in explaining our confidence in the fact of evolution, while acknowledging that we still struggle to understand how the process works—we are as confident that creatures evolved as we know that the earth goes round the sun, not vice versa:

> Without knowing or pretending to know the way of operation of the secondary cause, the vast increase of knowledge-stores of biological phenomena makes it as impossible to comprehend them intelligibly in any degree, on the assumption of primary or direct creation of species, as it was impossible for Copernicus to understand and explain the vast accession of astronomical facts, on the belief of the subservient relation of sun to earth.

Yet, however comfortable Owen became with the fact of evolution, he loathed Darwin's theory of natural selection as a potential explanation for its mechanism. His reasons were grand and interesting (however false by modern judgment), not petty and personal. Owen was the only prominent English representative of a great continental European tradition of thought that then set, and in revitalized form now motivates again, the deepest and most interesting debate about evolutionary mechanisms (more on this next month). Owen is the most misunderstood, and most unexamined, of all major English biologists of Darwin's era. Cardboard history, placing Owen with creationist baddies beyond the pale of scholarly interest, has enforced his eclipse—and I recommend a study of his life and work to any budding historian of science.

Owen rejected natural selection on two major grounds. He recoiled, first, from its materialistic premise that what we call evolutionary progress does not arise for itself and by its own laws but only as the side consequence of an immediate struggle among organisms for reproductive success. Secondly, he decried Darwin's "externalism"—his reliance upon selective pressures imposed by environmental change to provoke responses by organisms. Instead, he searched for laws, internal to the nature and structure of organisms, that would set the pathways of evolutionary change.

In these non-Darwinian approaches to evolution, Owen followed the great "laws of form" tradition, popularized in Germany as *Naturphilosophie* and in France as the transcendental morphology of Etienne Geoffroy Saint-Hilaire (see my column of November 1985). These scientists sought rational principles of organic change acting prior to any immediate pressures imposed by environments—deep structural rules that would channel evolution along predictable paths. Other evolutionary theories—Darwin's and Lamarck's included—are primarily functional in viewing change as provoked by a need for new forms and behaviors in changing environments. The contrast of structural and functional approaches is as meaty an intellectual debate as any that ever graced biology.

Owen felt that certain features of *Archaeopteryx* supported his laws-of-form approach against Darwinian functionalism—and he said so with verve and satisfaction. In his 1863 paper, Owen explained two features of *Archaeopteryx* as illustrating his search for laws of form. First, Owen noted that *Archaeopteryx* differs most from other birds in the form of its tail. Since a major principle of his rational morphology held that structures most variable within groups should be more labile in evolutionary lineages, Owen pointed out that tails are the most variable element of vertebrate skeletons—consider, he wrote, long- and short-tailed forms of bats, rodents, and pterodactyls (we never find creatures short- and long-headed to such a degree). He was delighted that a structure with inherently greatest potential for change should mark the largest difference between *Archaeopteryx* and later birds.

Another principle of rational morphology held that evolutionary progress usually followed a path of continuous departure from the simplest and most general form of embryos within a general group. On this criterion, early stages in the history of a lineage should retain embryonic (primitive)features as adults. Owen noted that "all birds, in their embryonic state exhibit the caudal vertebrae distinct," but that vertebrae later coalesce to form the stout and stubby tail of adult birds. *Archaeopteryx*, with its numerous unfused vertebrae, and consequently lengthy tail, therefore retained the embryonic form of more advanced birds—an appropriate status for an ancestral form in a world of rational morphology. Owen wrote, with a composite adjective rivaling anything any German ever composed:

> In *Archaeopteryx* the embryonal separation persists . . . . Thus we discern, in the main differential character of the by-fossil-remains-oldest-known feathered Vertebrate, a retention of a structure embryonal and transitory in the modern representatives of the class, and a closer adhesion to the general vertebrate type.

In summary, then, Hoyle's impugning of Owen collapses on two major grounds. Owen would not have risked the museum he loved, and to which he dedicated his professional life, for some supposed and tortuous victory against Darwin—especially in 1862, at a most crucial and sensi-

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Little Girl and Her Doll

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tive moment, as he first tried to gain momentum for a parliamentary bill to establish his institution. Second, *Archaeopteryx* could provide no possible victory for Owen's true opposition to Darwin. *Archaeopteryx* spoke for evolution, but Owen was an evolutionist. Moreover, Owen read this first bird as support for his own theory of rational morphology against Darwin's functional views.

I can forgive Fred Hoyle for his error about the slab and cement; we all make a whopper of a mistake once in a while, and science must tolerate and explore the most unconventional proposals. But I cannot smile so benignly upon his misuse of history. If Hoyle had spent but an hour or two actually reading what Owen wrote about *Archaeopteryx*, rather than ripping off the cardboard history for his own purposes, we would have been spared this wasteful and hurtful incident in folly. I do not advocate any unthinking ancestor worship, but scholars do make a tacit pledge when they enter this exacting profession—to honor the struggles of those who have gone before and to treat arguments with respect and integrity. The simplistic versions of bad and old versus good and modern may boost our pride in science as above and apart from other human struggles, but these cardboard moralisms come home to roost.

If I surprise you with my uncharacteristic vehemence, consider the consequences. Careers are fleeting, and nothing is more precious to a scholar, or in such short supply, as time. My colleague Alan Charig had to spend months learning nothing new, developing no new techniques, all in the soul-destroying and strictly negative task of refuting a vacuous hypothesis, carelessly and irresponsibly made from the first. Meanwhile, newspapers, with their ethic of promoting controversy, their limitations of space, and their levels of detail, cannot convey the decisive character of his refutation—and the public is left hanging in the air by this "but-on-the-other-hand" style of reporting. For example, a recent *Boston Globe* article (May 19, 1986), while presenting Charig's case convincingly in the body of its account, nonetheless concludes: "There the affair stands, with Hoyle and his colleagues crying cover-up and demanding tests. Charig is not about to capitulate." Scientists find themselves in Catch-22. The more we beef, the more we are branded as dogmatists. If we respond vigorously to an outrageous claim, we stand accused of hysteria. Thus, the most irresponsible ideas often get the best press.

Let me end on a happier and productive note. When we break down the cardboard histories that promote science as separate and better, we begin to understand the common ground that unites all intellectual struggle. How lovely then that *Archaeopteryx* can also serve as a symbol of unity between art and science. *Archaeopteryx* lies on a slab of the famous lithographic limestone of Solnhofen; its formal name is *Archaeopteryx lithographica*. The same uniform and fine-grained sedimentation that permitted the preservation of feathers has also set the use of this stone among artists the world over—for virtually all the world's great lithographs, from the invention of the technique to artistic studios throughout the world today, have been drawn upon stone from the Solnhofen quarries. I close, as I never have before, with a picture—the first ever published of *Archaeopteryx*. This lithograph of the first specimen ever found, the single feather, was published in 1862—

Palaeontographica

and it was drawn upon Solnhofen stone from the same quarries. What a fitting and pleasant end—to contrast Hoyle's hurtful and silly charge about artifice with the true and proper way to practice the art of drawing feathers upon the very same material.

Stephen Jay Gould teaches biology, geology, and the history of science at Harvard University.

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Foul Shots and Rifle Fire

Basketball in northwest Pakistan, is only a game

by R. Lincoln Keiser

Field Diary: May 28, 1984

At about eleven o'clock this morning, Qai Azgul left after exchanging gossip and requesting medicine for his wife's illness. When he reached the road, rifle shots rang out from the high mesa dominating the approach to my house. Although the bullets hit close to his feet, Qai Azgul sauntered down the road with his usual swagger.

Field Diary: June 4, 1984

At seven fifteen this evening, my supper was interrupted by the sound of automatic fire from AK 47 assault rifles. The shots were coming from the neighborhood where Qai Azgul lives. The fire fight lasted about thirty minutes. At about eight o'clock, a jeep arrived in front of my house with Qai Azgul writhing in agony on the back seat. He had been hit twice, but fortunately both of the bullets had exited without damaging a bone or vital organ. After I had bandaged Qai Azgul's wounds, my driver drove him to the hospital in Peshawar.

Field Diary: June 15, 1984

Qai Azgul returned from the hospital today vowing revenge. Although public meetings are planned to attempt a peaceful settlement, no one really believes that Qai Azgul will forgo revenge.

Field Diary: June 20, 1984

I returned from Islamabad today to learn that on June 17 another pitched battle had broken out between Qai Azgul, supported by his *ja* (literally brothers, but in this case, paternal cousins), and his enemies. Although attacked from two directions, and by a force superior in numbers, Qai Azgul and his kinsmen were able to defend themselves because they possessed more automatic rifles than their attackers. The fight began in the early evening and lasted until well after dark—about three hours altogether. During this time the sky was lit with tracers, and bullets were flying in all directions. The fight was finally halted by a group of elders who, ignoring the bullets, walked between the two groups of combatants, forcing them to stop firing.

I wrote these journal entries while doing anthropological field research in Thull, a Moslem tribal community located in the Kohistan section of Dir District, in the Northwest Frontier Province of Pakistan near the Afghan border. They illustrate the importance of *mar dushmani*, or blood vengeance (literally, death enmity), in the social life of the community. One cannot live in Thull even for a day without becoming aware of the pervasiveness of organized violence.

The array of weaponry itself is astounding—a genuine storehouse of arms. Men own specially made fighting knives, axes, clubs, walking sticks designed to double as stabbing spears, automatic pistols, revolvers, bolt action rifles, updated versions of nineteenth-century British army cavalry carbines, and the prize pieces: Kalashnakov AK 47 assault rifles. One even finds bolt action versions of the AK 47, designed and produced by the local cottage arms industry. The sounds of Thull reflect its weaponry. Shots are heard continually during the day and often in the night as well. Religious authorities have almost succeeded in stamping out singing and drumming; in their place gunfire has become the music of Thull.

Although I had come to Pakistan to study organized vengeance, I was surprised to find *mar dushmani* so entrenched among the Kohistani, since earlier reports by anthropologists had led me to believe that within that ethnic group, internal disputes were generally settled without bloodshed. Yet according to most people in Thull, vengeance-related murders, assaults, and small-scale battles have increased dramatically in recent years. Hard statistics are difficult to come by, but the captain in charge of the small contingent of police in Thull (population 7,000) reported that, during his two-year tenure in office, murders averaged two per month. With a shake of his head he declared that the people of Kohistan are among the worst, most lawless people in Pakistan, and those in Thull the worst in all of Kohistan.

Getting to Thull from Islamabad, the capital of Pakistan, was no small task. The road leads across the Indus River and the plains of Malakand to the foot of the Hindu-Kush Mountains, then snakes over the treacherous Malakand Pass to Chakdarra. It was near here that a small contingent of British soldiers (including the young Winston Churchill) fought off a determined attack of 6,000 Pathan tribesmen in the Yusufzai uprising of 1901. From Chakdarra the road winds its way up the Panjkora Valley to Dir town, the market and administrative center for Kohistan. The road is paved to Dir town, but Thull lies some forty miles beyond, at the end of a dirt road impassable in bad weather.

The existence of the blood feud was not the only surprise awaiting me in Kohistan. As I approached Dir town, there—on an ancient river terrace overlooking the Panjkora River—was a basketball court! To be sure the surface was dirt, the backboards were wood, and only a few strands of cord hung from the rims. But it was a

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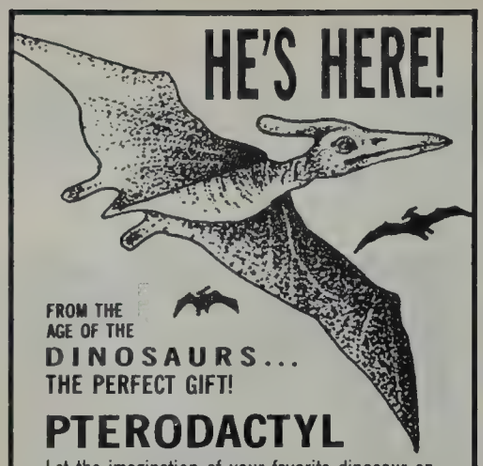

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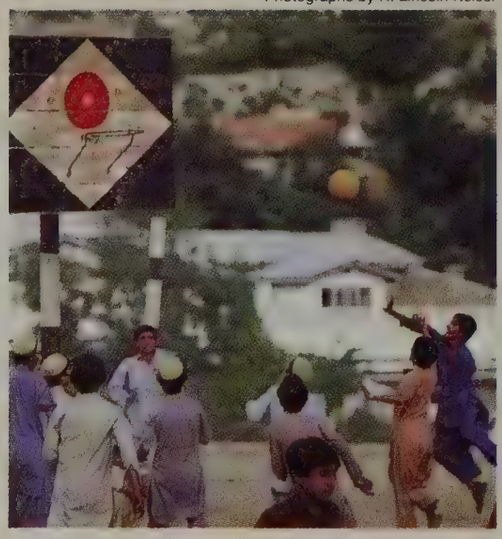

In Dir town, the ball is often propelled like a bullet from a rifle.

basketball court nonetheless, with the out-of-bounds lines, half-court lines, lanes, and foul lines scratched out with a stick.

For some time I have been an avid participant-observer of pickup basketball, and one of the major sacrifices I had expected to make when I left the United States for research in Pakistan was my daily afternoon basketball fix. Here was an opportunity not only to dazzle the local crowd with a few hook shots but also to explore some ideas about the relationship between games and culture. After I made friends with a few of the players, I was invited to participate; in all I played in six games during visits to Dir town.

Not surprisingly, the game in Kohistan differs from pickup basketball played in America. The basketballs, imported from China, usually deviate in weight from official NBA standards. They are available in the bazaar, where they are sold in general merchandise shops, along with soap, radios, toys, insecticide, and bullets. The shot repertoire consists of standard layups off fast breaks and of running, jumping push shots in which the ball, rather like a bullet fired from a rifle, is propelled toward the basket at high velocity. No one has the shooter's touch, but the ball goes through the basket an amazingly high percentage of the time nevertheless—if the shot is completely clean. Otherwise the ball ricochets at least twelve to fifteen feet off the basket.

Dribbling and passing skills are nominal as well, not surprising since the surface of the court is creased by gullies and littered with stones, boulders, and other refuse (the court is a favorite stopping place for nomads on their way to and from summer pastures, and their goats, sheep, and camels leave unforgettable memories). Thus a player attempting to dribble must focus entirely on the basketball, otherwise he will either lose control or, worse, hit a camel pie. The concentration on the ball means that dribblers have difficulty seeing their teammates' cuts to the basket, and even so the ball usually bounces unpredictably off a rock, depression, or other obstacle when dribbled more than three or four times. Similarly, bounce passes almost invariably go awry.

Setting picks is unheard of (this is a strategy in which an offensive player stations himself so as to block out the defensive player guarding a teammate. The purpose is to free the teammate for an unhindered shot). Given the clouds of dust rising from the court, picks would be superfluous in any case. In lieu of picks, clever players sometimes use debris on the court to force the defense into giving them room to shoot (or perhaps more accurately, "rocket") the ball at the basket. Although anarchy seems to typify the flow of motion, the game is played with incredible exuberance. And at an altitude of 6,500 feet, it was without doubt the most exhausting basketball I ever played.

What is perhaps most striking to aficionados of American pickup basketball, however, is the difference in rules. In the United States, players themselves call fouls, and unlike the procedure in refereed games, no one shoots foul shots. Rather, possession of the ball is awarded to the team against which the foul was committed. Games are played to an agreed number of points, usually 9, 11, or 15, with each basket counting as one point. Kohistani pickup games, on the other hand, are always played with a time clock and referee. Field goals count 2 points, and foul shots 1 point. Although the length of games varies, they are always played in the early evening, and they unvaryingly end at the same time. The winner is the team with the most points at precisely ten minutes before the call to evening prayer.

The referee was always the same older man—dignified in demeanor, quiet but firm in tone of voice. He is a man of substance in the community and, more important, a respected elder in a clan with many rifles at its disposal. No one ever argues with the referee. In fact, no one ever argues at all. While in pickup games in the United States even normally mild-mannered college deans and professors occasionally let fly with a choice Anglo-Saxonism, it's quite the opposite in Dir town. There, no one hears even the hint of a raised voice, much less a strong word. Although the game is competitive, in Kohistan the basketball court is not the place for expressing intense emotions.

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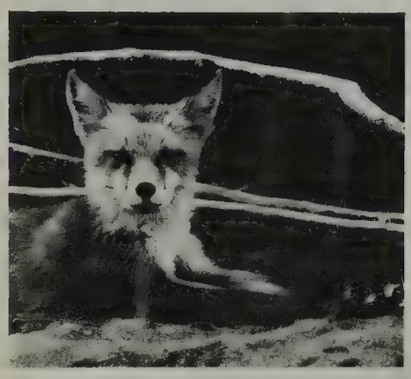

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skills of the players, the rules limit physical contact to rare, isolated instances. For example, if two players from the same team touch a rebound at the same time, the ball is immediately turned over to the other side, and if a rebound is touched at the same time by opponents, the ball is awarded to the defensive team. The consequences on style of play are obvious: offensive players never rebound aggressively, no one "crashes the boards," and no one fights for position under the basket. Limited physical contact thus discourages expressions of violence, hostility, and anger.

While Kohistanis value the use of physical violence and expect men to present themselves as warriors with quick trigger fingers, they play basketball in a friendly, almost offhand manner. In America, however, where men are expected to control the expression of hostile feelings in "real life" competition, pickup basketball is played with fierce concentration. Physical contact, swearing, and arguing often punctuate play, and athletic contests in general are serious (indeed, almost sacred) undertakings. The Little League father who hounds his son's coach, the college coach who forbids his players to hold hands with their girl friends, and the runner who believes God is at the top of the next hill are not simply cultural parodies.

At an early age American males learn that success in sports gains respect—and that success is closely connected to winning. By the time many boys reach adolescence, winning or losing has come to be one of the most critical measurements of self respect, and to lose in sports is a metaphor for failing in life. To call unsuccessful people "losers," as Americans commonly do, reveals a view that reality is, in some ways, a kind of athletic contest. Thus in pickup basketball, even mature American men, secure in themselves and in their social position, often express how much they love to win. And who can doubt their words, for they play with ferocious intensity, and they always keep score. As I have often heard expressed on the court, "I hate to lose!"

While American men often claim to play pickup basketball in order to exercise, lose weight, or release tension, in themselves, these reasons are incomplete. Men could exercise in a variety of ways, but those who play basketball often complain that skipping rope, swimming laps, chopping wood, and other similar activities are a bore. The drum-rolled television motto, "The thrill of victory, and the agony of defeat!" strikes a more responsive chord because it plays on the drama inherent in athletic contests. Pickup basketball allows American men to experience first-hand clear-cut victory and defeat in a complex social world, where real victory and defeat are often shadowy, unclear, and constantly changing.

Kohistanis, militant Moslems that they are, would find this nearly sacred treatment of sports ridiculous, if not downright blasphemous. For Kohistanis pickup basketball has a different meaning, one closely connected to historical developments in the district. In the mid-nineteenth century Dir was an area in which local khans (tribal political leaders) were locked in continual, often bloody struggles for hegemony. Alliances and oppositions shifted as ambitious men sought to further their aspirations at the expense of rivals. In 1849, with the formal establishment of British rule in the plains of Malakand, a new player entered the game. Now, the struggles for supremacy among the khans became one small play in a larger contest—the "great game" between the British and Russians.

The plains of Malakand were an area rich in agriculture, and as such, a profitable addition to the holdings of the British East India Company. At least a degree of tranquillity was necessary in Malakand if British trade and commerce were to flourish there. The politically unsettled conditions in the mountains of Dir above the Malakand Pass constantly threatened to spill onto the plains, thereby disrupting peace and threatening profits. In addition, as the Russian Empire expanded in central Asia to the northwest of India, the protection of India's northwest border became an obsession with the British.

Initially, British officials adopted a hands-off policy for all the mountain areas bordering the Malakand plains. Later, however, to protect against the Russian threat, they actively encouraged the establishment of a state in Dir whose ruler they could control. Largely as a result of British support, Sharif Khan, a Yusufzai Pathan, succeeded in establishing himself as ruler. The Kohistani communities of the upper Panjkora Valley were incorporated into the new state. Throughout the remaining days of the British raj, the maintenance of a friendly government in Dir was a cornerstone of British colonial policy. To this end, Sharif Khan was awarded the title nawab and given arms, subsidies, and specially arranged meetings with the British viceroy in Simla. But most important, he was given nearly carte blanche to rule as he saw fit.

Sharif Khan was a hard, cruel, and often capricious ruler. He considered Dir his own personal estate, neither adopting nor developing any formal legal code to regularize his rule but governing instead by

rbitrary decree. In order to weaken potential opposition, the nawab borrowed a version of the divide-and-rule policy of his British masters. He promoted local strife among his people by levying light fines for murder, while at the same time advocating that injured parties take vengeance rather than accept compensation. This policy was instituted under the guise of promoting *badal* (revenge), a key value in *pakhtunwali*, the code of the Pathans. Under the nawab, *pakhtunwali* values became firmly entrenched even in the ethnically distinct Kohistani communities.

The nawab also attempted to keep the communities of Dir cut off from surrounding areas. Few roads were built in the district, and no schools were permitted. As part of this policy, the nawab permanently exiled any man who left the district to attend school elsewhere and confiscated his family's land. Following independence in 1947, the newly created government of Pakistan assumed control of the Northwest Frontier Province, although internal affairs in Dir remained under the direct control of the nawab. When tension developed between the nawab and Pakistani officials over his opposition to social and economic development, Sharif Khan was forcibly deposed, and in 1965 the Pakistani government assumed direct administration of Dir.

After the nawab's fall, a new era began in Dir. The Pakistani government immediately embarked on an ambitious program of social and economic development. A large, relatively modern hospital complex was built in Timargara, Dir's administrative center; schools, administrative offices, medical clinics, police posts, and post offices were constructed in all parts of the district, including the most remote mountain regions; and the construction of a road system began to link hitherto isolated villages with the rest of the country. When bus service was initiated, travel both within and outside Dir became comparatively easy. In the 1970s electricity was installed in Panjkora Valley as part of an ongoing rural electrification program; and with the establishment of a national television channel, programs (including "Kojak" and "Trapper John, M.D.") were beamed to Dir. In Dir town itself a high school, college, medical center, telephone exchange, and two bank branches were opened.

Economic development in Dir created new networks of social interaction. During the nawab's reign, all social relations were organized along family, clan, community, and ethnic lines. In the years following his fall, however, distinctions in education and occupation began to intrude. Gradu-

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The Dir town basketball court is a favorite camping ground for nomads.

ates of the local schools, along with outsiders possessing similar educational credentials, were hired to teach in the schools and to man the telephone exchange, post office, clinic, bank branches, and government bureaucracies. The development of large-scale timber operations in Kohistan added to the number of semiprofessionals and petty managers living in Dir town.

Emerging social groups with claims to high status often symbolically mark their distinctiveness. In Dir town, professionals and managers, whose status is largely determined by education, now set themselves apart in a variety of ways. To demonstrate their education and thus symbolize their elite status, they wear clothes of the correct cut and made from high-quality cloth, show good manners as defined by urban Pakistani society, and speak fluent and grammatically correct Urdu and Pushtu (as well as some English). Language, dress, and manners, however, are symbols that anyone is free to adopt, and thus the social boundaries they mark are often fuzzy and indistinct. In Dir town a clearer way to mark such boundaries is through competitive sports.

In 1975, a small group of high school and college graduates who had learned to play Western sports in school organized the Shalimar Sports Club around three sports: basketball, volleyball, and cricket. Each sport had designated captains and team members. Initially, members of the club competed only against one another in Dir town, but later the club entered teams in district-wide and provincial tournaments. During the following ten years, through a series of formal athletic competitions, a network developed in Dir district linking men of similar interests, educational background, and occupation. Participation in sports began to emerge as a mark of elite status. Today club membership totals about fifty men, and most, if not all, hold managerial or semiprofessional positions.

No one in Dir town claims (at least publicly) that membership in the sports club is exclusive in any way. Such claims would arouse jealousy, and in Kohistan, where violence always lurks just beneath the surface, jealousy could easily prove fatal. In theory, membership is open to anyone—anyone, that is, who knows how to play the games. But school graduates are the only people who possess the required knowledge of how, for example, to play basketball with a time clock, referee, and foul shooting. Thus even evening pickup games, technically open to all members of the community who know the rules, are actually limited to club members (who are given priority) and high school and college students who will undoubtedly join the club in the future.

The class loyalties manifested by membership in the Shalimar Sports Club crosscut more traditional distinctions. The members continue to be pulled by deep-rooted family, clan, and tribal obligations and allegiances. Just as important, Kohistanis are Moslems to the man, and male sense of self is not symbolized by winning or losing in sports, as it is in America, but instead rests on a religious foundation, that of Islam.

For Kohistanis, Islam is basically a matter of *iman*, a concept with two distinct but interconnected meanings. On the one hand *iman* simply means "faith," while on the other it means "blessing" (or, perhaps better, "gift") from God. For most Moslems, *iman* as faith comprises a number of tenets—for example, the belief in the unity of God and his omnipotence. For Kohistanis, however, the critical element in *iman* is the notion of *ghrairat*. *Ghrairat* generally means "honor," in the sense of personal worth and integrity. Because it defines men as basically worthwhile, it is seen as one of God's most valuable gifts. Its defense is a responsibility every man owes God. As Kohistanis explain, *ghrairat* is part of *iman*, a gift from God, and, therefore, natural. Every Moslem man is born with it, and although it can be dirtied by others, as one's shoe is dirtied by stepping in excrement, it can only be lost by the failure of its owner to protect it.

Protecting *ghrairat* depends on following a clearly defined code of conduct. To a large extent this involves acting in particular ways toward female kinsfolk, but more important, the code demands that men be ever ready to create relationships of "death enmity" and seek revenge when their *ghrairat* is sullied. Reflecting light from a mirror on a man's wife, killing his close male kin, physically or verbally abusing his person, sully his *ghrairat* and demand instant vengeance on his part.

Because *ghrairat* is a quality imbued with sanctity by its association with Islam, it lies at the core of the Kohistani self, and for most men—even the educated elite—its protection is worth almost any risk. Thus if pickup basketball were played in Dir town as it is in the United States, games could quite easily escalate to gun battles, since *ghrairat* demands retaliation for the kind of physical contact and verbal abuse common in the American game. Then club members would be compelled to oppose one another in terms of traditional family, clan, and tribal loyalties against which fledgling class allegiances could never stand. In no time at all the Shalimar Sports Club would be obliterated.

Therefore, members of the Shalimar Sports Club must play basketball in ways that exclude the possibility of violence. Where participation in the game itself defines elite status, winning or losing is not the most important concern. With so many real issues to fight about, why break asunder social relations and even risk death over basketball? After all, in Dir, unlike in America, it really is only a game.

R. Lincoln Keiser is associate professor of anthropology at Wesleyan University in Middletown, Connecticut.

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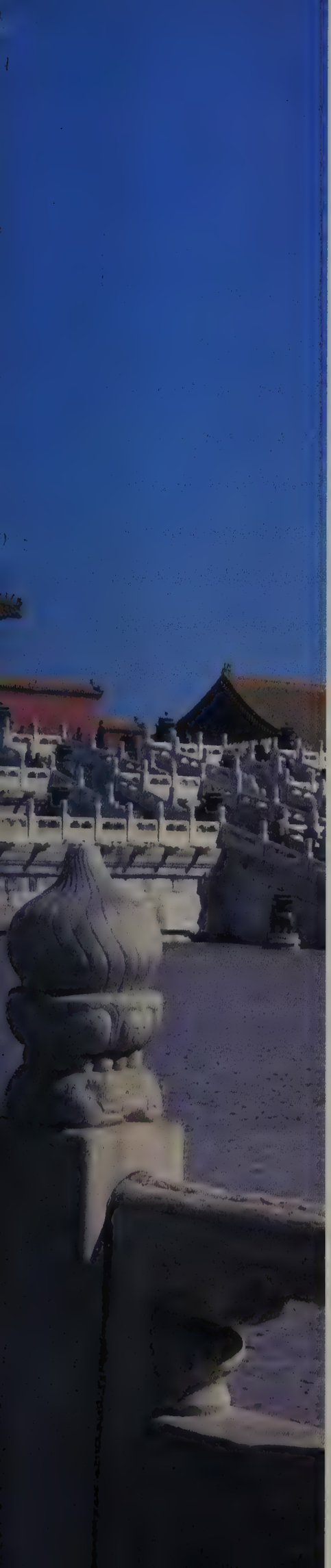


The Hall of Supreme Harmony in Beijing's Forbidden City was built in 1697.

China's Venerable and Glorious Architecture

The construction methods of its distinctive buildings evolved more than 2,000 years ago

by Xu BoAn and Guo Daiheng

Concave roofs with gracefully upturned eaves, decorated tiles, distinct roof ornaments, complex bracketing, and airy interiors—the unmistakable features that characterize Chinese monumental architecture (temples, palaces, pagodas)— developed over millennia and ultimately influenced building design throughout Asia. Unlike other architectural systems of the ancient world, the Chinese system has kept its original characteristics for 2,000 years. Its distinctive roof and support design has proved adaptable to diverse environments from the steppes of central Asia to the subtropics of southern China. Such unity of style was nonetheless expressed in an abundance of forms. According to some historians of Chinese architecture, these forms matured during the Tang dynasty (A.D. 618–907) and mellowed in the next dynasty, the Song (960–1279), after which they slowly began to show signs of rigidity.

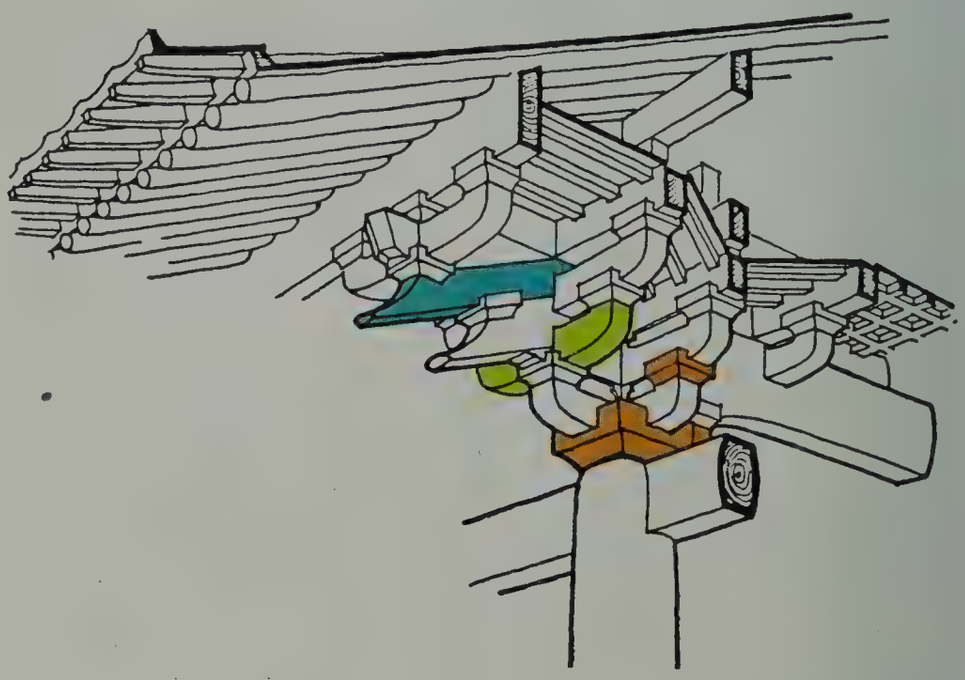
The buildings of ancient China were timber framed and their upturned roofs became the quintessential element of the architecture. Unlike Western construction, the roofs of Chinese buildings were supported by columns rather than walls. This was accomplished by means of a complex bracketing system known as the *dou gong*. Concave roofs, columns, and bracketing make up the essential characteristics of Chinese building design.

The origin of the Chinese concave roof has puzzled many scholars in both the East and the West. According to some, it imitates the curve of a central Asian tent; others have guessed that it turns up at the eaves to allow more sunlight to penetrate into the room below or to facilitate drainage. The upturned roof did not appear in early Chinese architecture but evolved gradually. The corners of the roof typically had small ceramic animals mounted on them. Although these animals were primarily decorative or symbols of good luck, they may also have protected the wooden pegs attached to the roof ridge from erosion during rain.

The *dou gong* bracket is a three-part, cantilevered structure: the *dou* (which means a square box) is a small block of wood, several of these form the column capitals and are the bases for higher building tiers; the *gong* is a squat, U-shaped wooden piece, two of these are crossed at right angles in each block to spread in four directions; and the *ang* is a long, slanting cantilevered beam that descends from the inner structure, balances on the top of the columns, and extends through all the dou gong brackets to support the outermost ones. The function of the dou gong is to support the overhanging eaves of the roof and at the same time to shorten the free span of the crossbeams. From a mechanical perspective, the composition of the dou gong is an ingenious structural solution for supporting a heavy roof. And in its successive variations it has served as a major feature in distinguishing Chinese architecture of different ages and styles.

The dou was first depicted on bronzes of the sixth and seventh centuries B.C., and the gong was first portrayed on a square bronze tablet unearthed from a tomb that dates back to the third to fifth century B.C. The dou gong evolved gradually from its early stage, when it was simple and had a clear structural function, into a more sophisticated, elaborate stylistic element. Later it was used for tiers of crisscrossed, overhanging frameworks, one on top of another. Although this later stage produced magnificent buildings, the dou

The dou gong *bracket system, below, was a hallmark of ancient Chinese wooden-framed architecture. Set as a capital on a column, it branched above to support the upper structure. The system had three parts: the* dou *(ocher), small blocks of wood that become the bases of succeeding building tiers; the* gong *(green), short wooden pieces crossed at right angles; and the* ang *(blue), long cantilevers, braced against upper beams, that extend down through the system at a 30° angle to balance on the column fulcrums and support the outermost eave brackets. The pagoda of the Fo Gung Temple, right, built in A.D. 1056, is the oldest and highest wooden structure surviving in China. Its roofs and railings are supported by* dou gong *brackets.*



gong's structural function eventually declined in the process.

Buildings made of stone or brick could stand thousands of years, but the earlier ones made of wood frequently collapsed or were destroyed by fire. Hence, the few surviving wooden structures a thousand or more years old have been cherished and carefully conserved. The Main Hall of Fo Guang (Buddha's Palace) Temple, built in A.D. 857 on Wutai Mountain in Shanxi Province, is one of these. Although the Buddhist Hall of Nan Chan Temple was built somewhat earlier (in A.D. 782), it cannot compare with the Fo Guang Temple in either scale or refinement. In building the Main Hall of Fo Guang Temple, the Chinese architects combined stepped beams with a triangular frame, using the dou gong system as the joint for beams and pillars. The hall was assembled with components fabricated on the ground, the conventional method of constructing timber-framed buildings in ancient China.

The Buddhist Hall of Fo Guang Temple, with its firm dou gong, extraordinary fourteen-foot eaves, gently sloping roof, spacious layout, and imposing architectural style, is a typical representative of Tang dynasty architecture. In addition, the numerous sculptures, wall paintings, and inscriptions that survive in the hall make this a valued relic of medieval China.

Another surviving wooden structure is the pagoda of Fo Gung Temple. It is the oldest wooden pagoda in China and, at 183 feet, the tallest surviving wooden structure. Pagodas are monuments that marked the burial of a Buddhist monk or an important Buddhist relic. Sometimes they stood alone, but often they were built as part of elaborate temple complexes that also had halls for meditation, residence, study, and teaching.

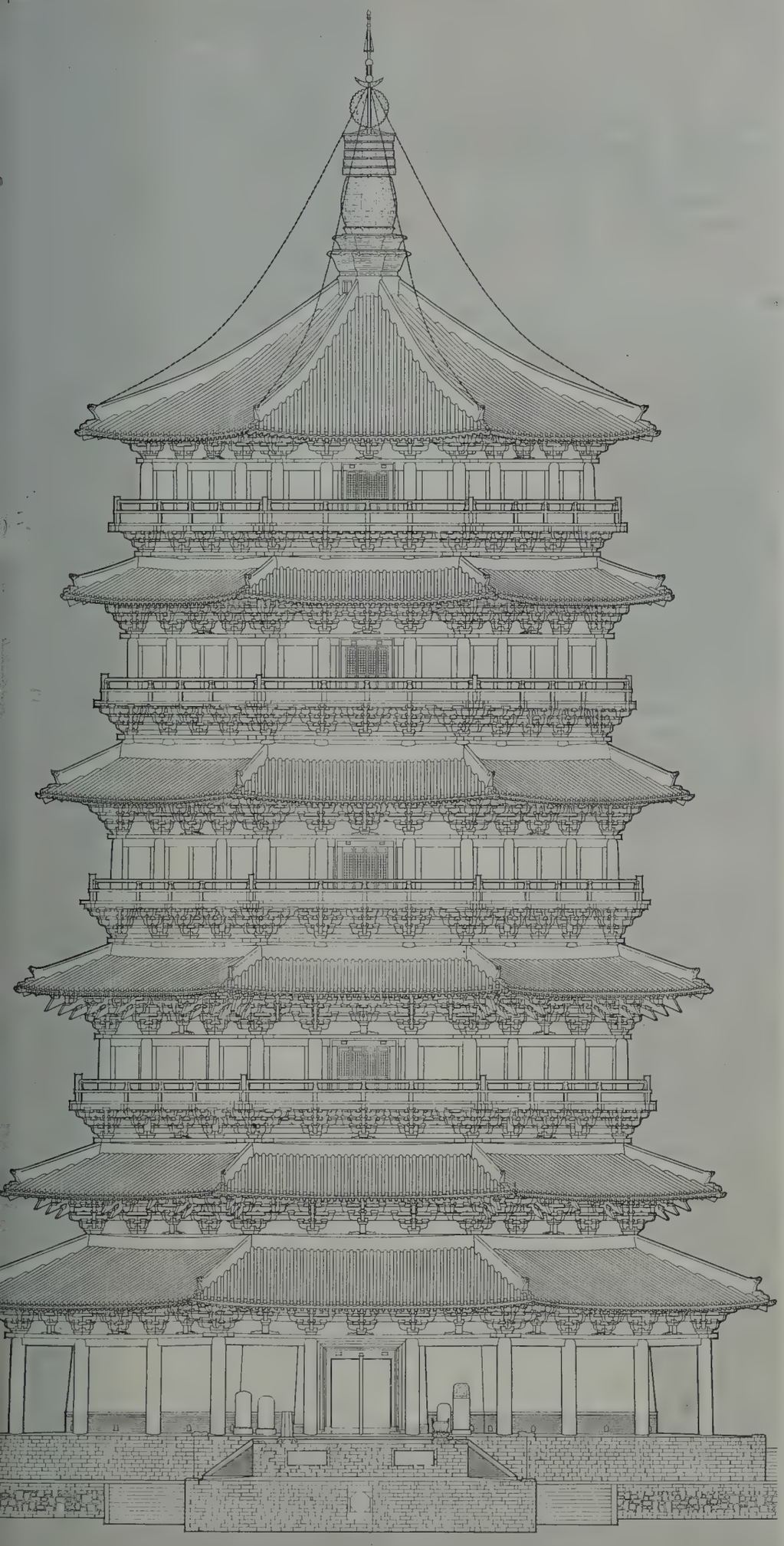
Buddhism was probably introduced into China from India about the first century A.D. A trickle of pilgrims, which grew to a steady stream by the fourth century A.D., made their way along the tortuous mountain and desert paths from China to the Buddhist holy land of India to study and returned to China to proselytize. In architectural terms, this mingling of cultures meant that the Indian Stupa, a bottle-shaped shrine that housed Buddhist relics, was eventually combined with the indigenous Chinese tower to form the ubiquitous Chinese pagoda.

Fo Gung Temple's wooden pagoda is an octagonal structure that, from the outside, appears to consist of five stories but actually has nine tiers. Between every two visible stories there is a hidden one. The upper stories become progressively smaller, making the building both proportional and stable. Seven times in its history, this wooden pagoda has been rocked by earthquakes, and during the wars of the twentieth century, it was hit by more than two hundred shells. Yet the temple survived the damage and it stands to this day, a monument to Chinese architectural accomplishment.

Among the various types of modern multistoried, reinforced-concrete buildings, the tube-shaped structure is considered one of the most promising for earthquake-prone areas, since it is thought to be flexible enough to withstand quakes without collapsing. The form of the Fo Gung pagoda is very similar to modern tube-shaped buildings. Two circles of columns, an inner and an outer one, are arranged within its octagonal plane, and the hidden stories are supported by both circles of columns, thus forming a rigid ring. A gently contracted, tube-shaped body is made by piling one circle of rings on top of another. In addition, all the wooden components of the pagoda are joined by brackets, enabling the pagoda to maintain not only rigidity but also a certain flexibility. In fact, this pagoda contains fifty-six different dou gong combinations and thus serves architectural historians as a veritable dou gong library.

Even older than the wooden pagoda of Fo Gung, is the brick Song Yue Temple pagoda in Henan Province. Built in A.D. 523, it is the oldest surviving Buddhist pagoda in China. In addition, it represents the country's oldest multieaved brick building. This pagoda has close-set eaves, unlike those that copy multistoried wooden pavilions or single-story pagodas that serve as tombs. One hundred and thirty-five feet high, it has twelve exterior sides, with a regular octagon in the interior. The base has an outer diameter of thirty-five feet and an inner diameter of about sixteen feet, and the wall is eight feet thick.

Over the course of several centuries,

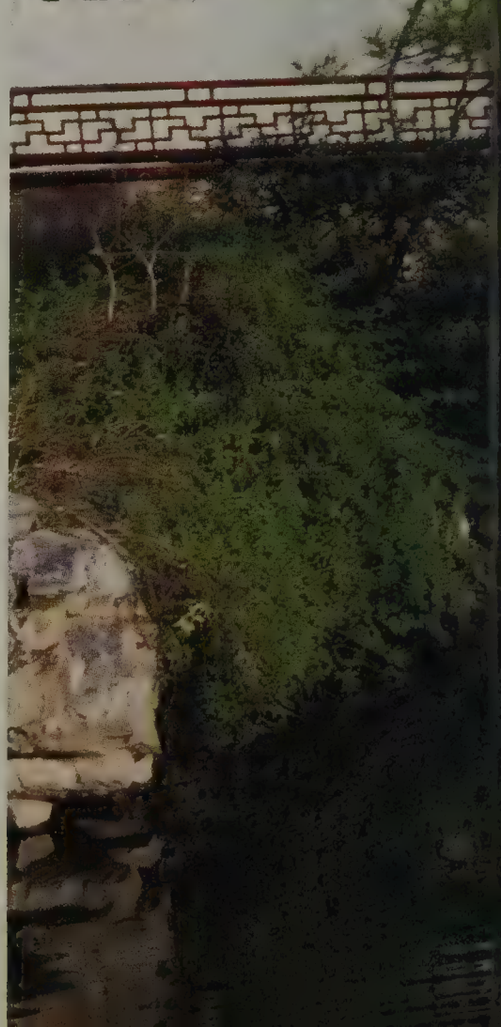


brick and stone pagodas generally evolved from structures with four to six sides to those with eight. Hundreds of these pagodas survive in China, but The Song Yue Temple pagoda, erected more than 1,400 years ago, is the only twelve-sided one, which, in addition to its early date, is why it is a rarity in China's architectural history and has become world famous. (Some scholars have speculated that it was a replica of an Indian Gupta-style temple copied by pilgrims.)

Aside from its unique shape, the Song Yue Temple pagoda is also known for its beauty. Built on the southern slope of the Song Mountains in eastern China, the pagoda is divided into an upper and a lower part. The upper section, which accounts for two-thirds of the total height, has fifteen layers of close-set eaves topped by a spire or finial. The eaves of corbeled (weight-carrying) bricks, diminish in size as they rise one on top of the other, giving the pagoda a vivid parabolic shape. The lower part is divided into two layers and forms the base of the pagoda. The bottom layer has four doors, each facing a different direction—north, south, east, and west. On the second layer, the principal story, four arched doors open at positions corresponding to those on the bottom layer, and together they form four tall, narrow doors. Resting on the other eight sides are reliefs of small, single-story square pagodas, each with a window. The surfaces of all the stone arch doors and windows are decorated with the halolike flame pattern that commonly encircles Buddhist deities. The inside of the pagoda is a hollow cavity that must once have had floors or stairs. Judging from the layers of brick-corbeled, overhanging eaves, there may originally have been as many as nine layers of wooden floors. This pagoda has stood for more than 1,400 years and may continue to stand for hundreds of years to come as evidence of ancient Chinese brick and stone architectural technology.

A world-famous structure of a very different kind is the 1,300-year-old Anji Bridge, which spans the Jiao River in Hebei Province, two hundred miles south of Beijing. Called the Great Stone Bridge by the local people, it was built between

Called the Great Stone Bridge by the Chinese, the open-spandrel Anji Bridge, below, has been standing for more than 1,300 years. A smaller bridge of this type was first built in Europe 700 years later. The Wang Shi Garden, right, is in Suzhou, on the lower reaches of the Chang Jiang (Yangtze). Known as the Venice of the East, Suzhou was shaped by water and once had fourteen canals running through it east to west and six canals north to south.



A.D. 605 and 617. The bridge has an arch span 115 feet long and 23 feet high. At the ends of the bridge, there are two open-spandrel arches. (A spandrel is the roughly triangular space between the curve of a small arch and the frame enclosing it.) The Anji Bridge looks smooth, slim, graceful, and light, like a crescent moon just visible in the clouds or a rainbow appearing after a rainfall. The designer of the bridge was Li Chun, a famous craftsman of the Sui dynasty (A.D. 581–618), who is known as the "the father of the open-spandreled arch bridge."

The central open arch of the Anji Bridge was formed by joining together, side by side, twenty-eight 10- to 15-inch-wide segmental arches to make up the total width of the central span. Unlike a stone arch bridge, built of only one segment, segmental arch bridges do not suddenly collapse from damage to any single segment. Such structures do, however, have a vulnerable spot – the weak linkage between the long but narrow segmental arches themselves. To overcome this drawback the designer used the "iron drag link" and "jointing iron" to hold the arches together. In addition, he narrowed the top of the bridge toward the crown so that the arches at both sides incline a bit toward the center.

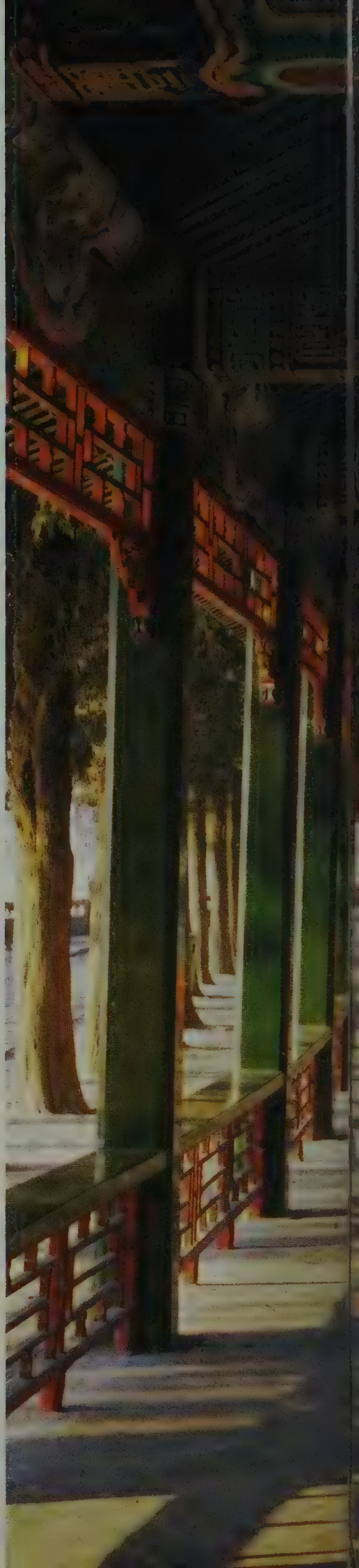
A bridge of this type did not appear in Europe (in Montauban, France) until the fourteenth century A.D., seven hundred years after the Great Stone Bridge, and even then the French bridge was built on a smaller scale. Not until the nineteenth century did the spandreled-arch bridge become widespread throughout the world. Therefore, the Chinese say that the Great Stone Bridge is both old and young at the same time.

Along with their other architectural achievements, the Chinese have been accomplished city planners since the seventh century B.C. Their urban planning was based on strict rules. Cities had to be sited in accordance with the "cosmic order"; this meant locating them on a strict north-south axis, with buildings facing south for warmth, as well as for the good fortune that was assured by alignment with the five directions (north, south, east, west, and center – which was considered a legitimate direction). Walls enclosed all cities, and conventionally, there were twelve gates, corresponding to the number of months and points on the zodiac.

Chinese cities were characterized by

The eaves of a glazed tile roof of the Imperial Palace, below, in the Forbidden City are decorated with typically Chinese animal figures. A 2,700-foot-long decorated and roofed corridor, right, snakes along Longevity Hill in the Summer Palace outside Beijing. The palace is actually a complex of pavilions, temples, gardens, and galleries overlooking a lake to which emperors and their families and entourages repaired in the summertime to escape the oppressive heat of the city.

George Holton: Photo Researchers



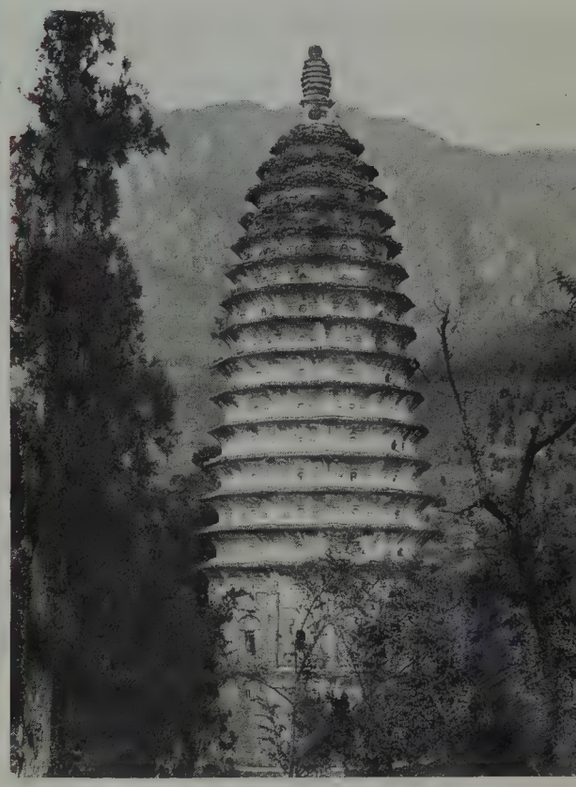
the centrality of government offices, whether the palaces of the imperial government or the office-residences of local administrators. Urban planning was the province of the state, with residences and markets controlled by the government. Likewise, the urban parks and lakes that formed important green belts were for the elite: either the imperial elite in the northern capitals or the growing merchant elite in southern cities.

As the core economic area of China moved from the north to the rich Chang Jiang (Yangtze) Delta area, successive emperors experimented with locating their capitals farther south, usually near Nanjing, which means "southern capital." Eventually, however, the heads of state moved their capital back to the north. As feared, the Mongols penetrated the northern frontier and conquered China in the thirteenth century A.D., establishing the Yuan dynasty (A.D. 1279–1368) and a new capital, at what is now Beijing (Marco Polo's Dadu), in Hebei Province.

After the Mongols were expelled, the project of building a new capital city on the ruins of the Yuan capital was started in 1406 by the third Ming emperor, but not completed until early in the Qing dynasty (1644–1911). The entire city occupied an area of about twenty-five square miles, with a length of 26,550 feet north to south and a width of 20,500 to 24,500 feet east to west. The city plan had an Imperial City to the north and a residential city to the south. Beijing represents a typical Chinese capital, with the Imperial City at its core. It is also the greatest surviving capital of a premodern empire.

The city originally had a strict symmetrical layout, with an axis passing through its entirety, as well as a symmetrical network of straight roads and avenues. The northern part of the capital was made up of three cities nestling inside one another: the Forbidden City was inside the Imperial City, which in turn was inside the high walls of the city of Beijing. Rivers and lakes were scattered throughout the Imperial City with expanses of green land around them. The imperial parks of the Ming (A.D. 1368–1644) and Qing dynasties were draped like an emerald necklace around the city. In addition, a northernmost string of three interconnected lakes provided water transport as well as boating pleasure. These blue and green belts not only beautified the environment; they also improved Beijing's climate.

The brick Song Yue Temple pagoda, below, tucked away in the mountains of the central province of Henan, is the only twelve-sided pagoda still standing in China. Built in A.D. 523, it rises to the unusual height of 135 feet and is considered early evidence of sophisticated Chinese technology.



The Forbidden City, the innermost nucleus, was the last bastion of Imperial China. Situated southeast of the three main pleasure parks, it measures 3,000 feet from north to south and 2,400 feet from east to west. Protected by a 160-foot-wide moat and a specially constructed, 35-foot-high wall, halls and pavilions stand side by side, and palaces with their own courtyards are laid out one after another. The total area of the Forbidden City is 250 acres; its Outer and Inner Court's contain nearly 1,000 buildings. The former includes the Three Great Audience Halls, with the Hall of Supreme Harmony the biggest and most important one; in fact, this hall is the largest single premodern building extant in China. Major official ceremonies took place in this hall during the Ming and Qing dynasties. The Inner Court, which functioned as the imperial living quarters, had three major palace groupings: the rear palaces, which included the official residence of the emperor, the Palace of Heavenly Purity, and that of the Empress, the Palace of Earthly Tranquillity, on the central axis; flanked by six East and six West Palaces for consorts and concubines; and behind them, six East and six West Palaces for princes.

Clustered together, the many palaces of the Forbidden City once housed emperors, empresses, concubines, princes, and princesses. Still protected by a moat and a high wall, the Forbidden City is now surrounded by high-rise structures.
Paolo Koch; Photo Researchers

Because the Forbidden City is on what was once a central axis that ran north to south through the whole city of Beijing, it shaped the city space and thus determined the city's layout. The introduction of tranquil lakes and surrounding parks into a bustling urban environment was such a great success that Beijing was considered a masterpiece of urban design.

The Summer Palace in the suburbs of Beijing, about five miles from the city, consists of Longevity Hill to the north and Kunming Lake to the south, regarded as the park's main attraction by the imperial entourage that went to the palace to escape Beijing's steamy summers. Longevity Hill is divided into two parts. The front hill to the south is a scenic area with large halls and pavilions, among which the Fu Xiang (Buddhist Fragrance) Temple and the Pai Yun (Orderly Clouds) Hall are the most imposing. At the southwestern foot of the hill lies a 2,700-foot-long corridor that acts like a colorful ribbon linking the buildings scattered over both flanks of the Orderly Clouds Hall into an organic whole. The series of buildings joined by the long corridor sets the tone for the design. The landscape of the back hill is quite different; with luxurious woods, it is fresh, quiet, and wild. A chain of lakes stretches north of the hill across a landscape that was intended to call to mind southern China.

Kunming Lake is also divided into two differently landscaped bodies of water. The lake nearer the palace is bordered by bridges, embankments, and a temple-filled island. But once on the lake, you have a clear, open view with a wide expanse of mist-covered water. The back lake presents a sharp contrast to the front; its winding course gives it an impression of size and depth, and its wilder landscaping suggests untamed nature. Even today, when boating on the back lake, Chinese can imagine themselves entering a fairy tale world of nature.

But today's Chinese face a difficult challenge: how to bridge the gap between the East and the West; how to preserve the irreplaceable relics of their ancient culture while at the same time adapting to the current wave of modernity. □

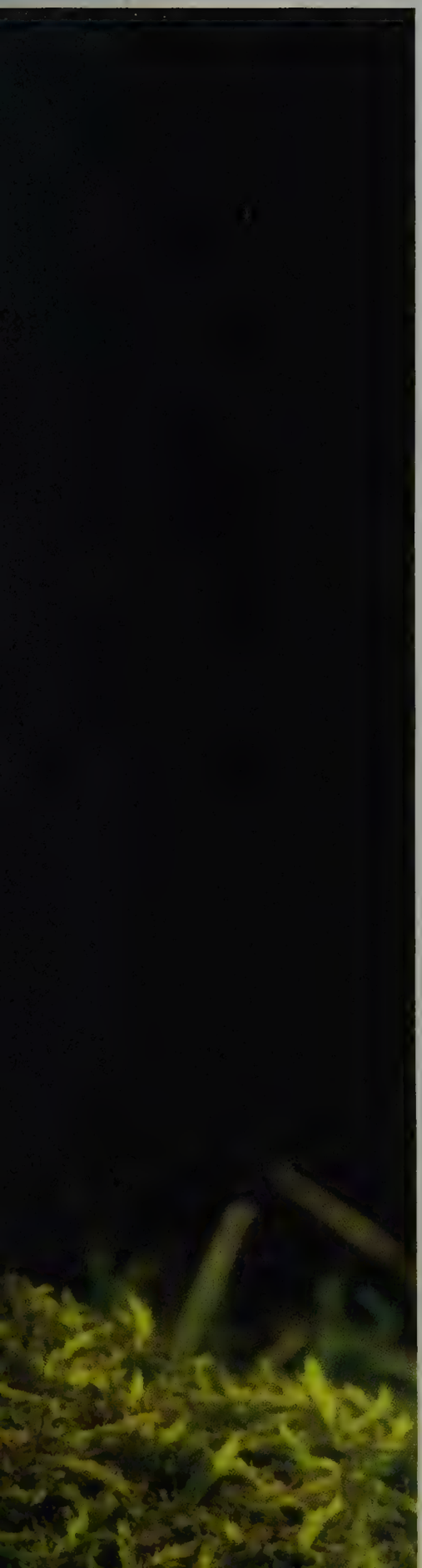
Mossy logs make convenient runways for mice, which apparently prefer traveling on the logs to traveling on the ground.

Joe McDonald; Bruce Coleman, Inc.

Getting Along in Appalachia

In mountain forests of Virginia, two species of mice live in harmony where, in theory, they should be in conflict

by Jerry O. Wolff



Leaning against the trunk of a white oak tree, I was for the sixth time that morning momentarily stumped by the mouse in my hand. Was it a cloudland deer mouse or a white-footed mouse, the species I had originally come to Virginia's Mountain Lake Biological Station to study? Keeping in mind that deer mice generally have a slightly more grayish coat, a longer, tufted tail, and are relatively smaller, I decided the little creature was a deer mouse and marked it down as such in my notebook. That made the tally for the day six deer mice, fifteen white-footed mice. I marked the sixteen-gram animal with a numbered ear tag and put it gently back on the ground.

Deer mice (*Peromyscus maniculatus*) and white-footed mice (*P. leucopus*) are two of the most common and widely distributed rodents in North America. In the west, the deer mouse is found primarily in grasslands, whereas the white-footed mouse, a more eastern species, prefers forest or shrub habitats. In parts of the eastern United States, however, the cloudland deer mouse, a subspecies of deer mouse, has adapted to cool, moist mountain forest habitats, where its range overlaps that of the white-footed mouse. In the oak-maple-hickory forests of the southern Appalachian Mountains where I work, white-footed mice usually outnumber deer mice by about three to one, but both species are common throughout the area and have apparently coexisted for many years.

When I learned of the coexistence of two such similar creatures in the same habitat I was intrigued; in fact, I noticed that up to six species of voles, mice, and shrews lived in these forests. This seemed to fly in the face of all the ecology courses I had taken, in which I was taught that similar species cannot coexist without dividing up the food or habitat in some way. Studies have shown that in grasslands, for example, meadow voles inhabit moist areas, while the similar prairie voles occupy drier sites. In desert communities, the kangaroo rat feeds in open areas on large seeds; in the same areas, the pocket mouse feeds under bushes on smaller seeds. In northern Arizona, as many as four species of wood rats coexist by living in different microhabitats and feeding on different foods. I soon began to wonder if the deer mice and white-footed mice were competing in ways not immediately apparent to me, and I decided to find out.

Before moving to Virginia, I lived and worked for seven years in Alaska, studying the behavior and ecology of mammals in the boreal forests near Fairbanks. There, the mammal community was extremely simple, consisting of snowshoe hares, red squirrels, taiga voles, and moose. Each species was adapted to its own, well-defined niche; their lives were geared to deal with the environment and to avoid predators, not to compete with each other. The Appalachian mice were my first chance to address the question of whether competition is in fact inevitable between similar species.

Over the course of five years, my students at the biological station and I carried out experiments to help us detect any competition between the two mouse species. An obvious place to begin was food. Our analysis revealed a remarkably similar diet. Both species fed primarily on beetles, butterflies, and other arthropods; blueberries, serviceberries, strawberries, and other fruits; maple, sumac, and trillium seeds; nuts, especially acorns; and lesser amounts of green vegetation. Their diets changed seasonally, but both species switched to the same foods each season. Acorns, primarily those from white oaks, were eaten in the autumn and winter, while summer fare included more fruits.

To learn more about the mice's microhabitats, we set 128 live traps on eight grids of two and a half acres each. (Since the animals are largely nocturnal, direct observations were limited.) We recorded the number and sizes of trees and shrubs, type of ground cover, and density of foliage in the area where each animal was caught; we found no difference between the two species. Then, since we knew that the mice spend some of their time up in trees, we wondered if they might be dividing up the habitat vertically. To find out, we dusted mice with fluorescent pigment powder and released them early in the evening to continue feeding and exploring during their normal nightly activity pe-

riod. The following evening, with the aid of ultraviolet lights, we were able to follow the trail of dust they had left the previous night. According to our results, deer mice spend about 22 percent of the time in trees, compared with 12 percent for white-footed mice. Both species thus spend four-fifths or more of their time on the ground. Clearly, the difference in use of ground and trees was not sufficient to explain their coexistence.

Next, we looked at nest sites, which we located by tracking animals with radiotelemetry. The mice usually nest alone, although males and females sometimes nest together during the breeding season before the pups are born. Each nest is about five inches in diameter and constructed of grass and dried leaves. Mice may have two or more nest sites in their home range and routinely move between them. During the winter, three to five nonbreeding mice frequently nest communally.

At first, our studies revealed what seemed to be a potentially significant difference: deer mice nested almost exclusively in cavities high up in large trees, while only about half of the nest sites of white-footed mice were in trees. The other half were either under rocks or logs on the ground or in burrows. Thinking that hollow trees and other natural nest sites might be in short supply, we placed wooden nest boxes on the ground and in trees. Although mice used both sets of nest boxes, our experiments produced no significant increase in the number of animals. Nest sites thus appear to be plentiful and not apt to be the basis for competition.

The classic way to test for the presence of competition is to determine whether the population of one species increases when the other is removed. For three years, we experimentally removed white-footed mice from our study area and found that deer mice did indeed increase in number and occupy the vacated habitat. Similarly, in the absence of deer mice, white-footed mice moved in. But the interesting thing was that in both cases, the rate at which mice colonized the empty habitat was not rapid and colonization was not complete; much habitat remained unoccupied. In only one out of the five years were the populations dense enough for mice to occupy all the suitable space. We do not know exactly what enabled the mice to reach such high densities, but a mild winter and good crop of acorns may have enhanced overwinter survival and reproduction. In the other four years, populations remained relatively low, even when we supplemented the food.

As our search for signs of competition continued, we wanted to look directly at the interactions within and between species. Our aim was to find out whether the mice were aggressive (and if so, under what circumstances) and whether they were territorial. Many birds and mammals aggressively defend the area in which they live, usually against members of the same sex and species. This defended area is referred to as a territory, in contrast to the home range, which is the larger, undefended living area of an animal.

Jerry O. Wolff

Contrary to expectation, deer mice and white-footed mice in the southern Appalachians frequently share the same habitat without competing in any way. Their diets, for example, are essentially identical, consisting of arthropods, seeds, acorns, berries, leaves, and other plant parts. Both species are capable of climbing high up in the vegetation in search of insects and seeds.

Karl H. Maslowski

Where two similar species use the same food and habitat, it may be adaptive- that is, increase an individual's chances for survival and reproduction- to defend a territory aggressively against members of one's own species, as well as members of the other species. And in these situations, individuals of one or the other species may prove consistently dominant, that is, better able to defend territory. This sort of territoriality occurs among similar species of blackbirds, chipmunks, and pocket gophers, but in these situations, the subordinate is forced into a different habitat. I, on the other hand, was dealing with two similar species in the same habitat.

We tested for dominance between deer mice and white-footed mice by conducting behavioral trials in a circular plexiglass arena thirteen inches in diameter and sixteen inches high. The arena was placed within the home range of one of the participants. The trials were between males and between females, within and between species. We found that the resident animal, whether male or female, was more aggressive, chasing and biting intruders and successfully excluding them from the arena, regardless of species. With neither species dominating the other, deer mice and white-footed mice thus appear to be functioning ecologically as a single species. Coexistence between two such similar species of mammals has not been demonstrated before.

Our arena experiments, of course, placed the animals together unnaturally. Observations under more natural circumstances convinced us that in four out of the five years, the mice were neither aggressive nor territorial. Rather, they maintained exclusive home ranges by avoiding one another. The mice were living out their lives in peaceful coexistence.

But what about the fifth year, when population densities were higher and the animals were aggressive? What were they defending that year? The key to answering those questions lay in territory size. In both species, males had larger territories than did the females, often overlapping considerably with neighboring males of both species. Females, in contrast, defended smaller territories and permitted very little overlap with their neighbors. And, interestingly, when we experimentally supplemented the food supply, the size of the males' territories did not change, while the females responded by defending even smaller territories: approximately 500 instead of 600 square yards. The reduction in territory size was the result of two factors: females concen-

Dennis W. Schmidt, Valan Photos

Below: White-footed mice may breed twice a year, in the spring and in the fall. Average litter size is three to four pups. The nests, made of grass and dried leaves, may be in a tree, in a burrow, or as here, on the ground. Right: Cloudland deer mice living in the Virginia mountains nest almost exclusively in trees, often in abandoned woodpecker holes.

T.J. Cawley; Tom Stack and Associates

trated their activity in smaller, food-rich areas, and some females immigrated from surrounding areas, attracted by the increased food supply. In all years, males' territories overlapped those of one or more females.

We concluded that males were not defending food or space per se, but rather trying to keep all other males—deer mice or white-footed mice—away from their mates. Since females mate only with males of their own species, the males were in a sense overprotective. But they may have no choice: our laboratory studies showed that males were equally attentive toward females of both species, which suggests that they cannot tell the difference. They may, then, have no alternative but to court both, leaving it up to the females to sort things out.

Although the females' behavior suggested that they were, in part, defending food, our laboratory work pointed up another factor: the danger of infanticide by intruding females. In a laboratory experiment, females attempted to kill the pups of unrelated females when their mother was removed from the nest. Infanticidal behavior was evident in both species and occurred between as well as within species. Females that we left with their newborn pups were more aggressive than nonmaternal females, attacking all females we introduced to their nest site. As pups became ready to leave the nest, mothers became less defensive. In the laboratory, aggressive mothers prevented infanticide; in nature, such behavior probably keeps strange females from entering another female's territory and killing her pups.

Females with young also spend less time foraging than do males and nonmaternal females, being away from the nest on average less than an hour, in contrast to the latter's foraging bouts of several hours. These short foraging bouts are probably designed in part to prevent infanticidal attempts. We did, however, observe one incident of infanticide in the field, in which an unfamiliar female killed five 8-day-old pups in a nest box while the mother was away. The intruder eventually took over both the nest and the territory. We speculated that an intruder's ultimate goal may be to acquire territory. Infanticidal behavior might be adaptive in years when populations are dense and space is limited, and since deer mice and white-footed mice use the same food and habitat, infanticide would be adaptive between as well as within species.

We began our study by asking how competition affected the life history of two similar, coexisting species. We expected deer mice and white-footed mice to exhibit ecological or behavioral features as a result of competition between them. But, like the mammals in the community I studied in Alaska, each species of mouse has adapted to its environment relatively independently of its presumed competitor. The reason is that competition can act as an evolutionary force only when some resource is in short supply, and as we discovered for deer mice and white-footed mice in our study area, the only resources that are even occasionally limited are females (for the males) and space to rear young (for the females). These limitations appear to be too infrequent to have led the species to diverge, behaviorally or ecologically. In other environments, where vital resources are limiting, competition does play a crucial role in structuring the community. For example, in desert communities of the Southwest, as many as fourteen species of rodents coexist by feeding on different-sized seeds or by living and foraging in different microhabitats.

We do not know yet what kept down the populations of deer mice and white-footed mice in our study site during four out of five years, but predation may have been a factor. The major predators of mice in this area are barred owls, long-tailed weasels, and rattlesnakes. Predation or some combination of environmental disturbances apparently keeps the population densities of the mice low. As our research continues, we hope to learn more about the long-term dynamics of the mouse populations. In the meantime, deer mice and white-footed mice thrive in the forests of southern Appalachia, free of both intellectual and—most of the time—real-world concerns about competition. □

The Island Sweepstakes

Why did pygmy elephants, dwarf deer, and large mice once populate the Mediterranean?

by Paul Y. Sondaar

The inhabitants of some Mediterranean islands thought the unusual bones they came across were those of saints or of dragons, but nineteenth-century paleontologists saw them for what they were: the fossils of pig-sized elephants and hippos. Most attributed the origin of these peculiar dwarf, or pygmy, mammals to the occurrence of degeneration (the deterioration or loss of function or structure in the course of evolution). They thought that the ancestors of these animals had been of normal size but that degeneration had occurred as the result of the inbreeding inevitable in small, isolated populations.

At the turn of the century, Dorothea Bate, a British scientist, began to collect these fossils systematically. In 1901, she visited Cyprus and obtained fossils of dwarf hippos for the British Museum (Natural History). A few years later she went to Crete, then under Turkish rule, where she masqueraded as a man in order to travel freely. Again she came home with a wealth of remains: dwarf hippos, dwarf elephants, dwarf deer, and large mice. The prevailing theory was that the ancestors of these creatures had originally reached the islands by crossing bridges of land and that the populations had been cut

Illustrations by D. L. Cramer

off from the mainland when these land bridges subsequently submerged.

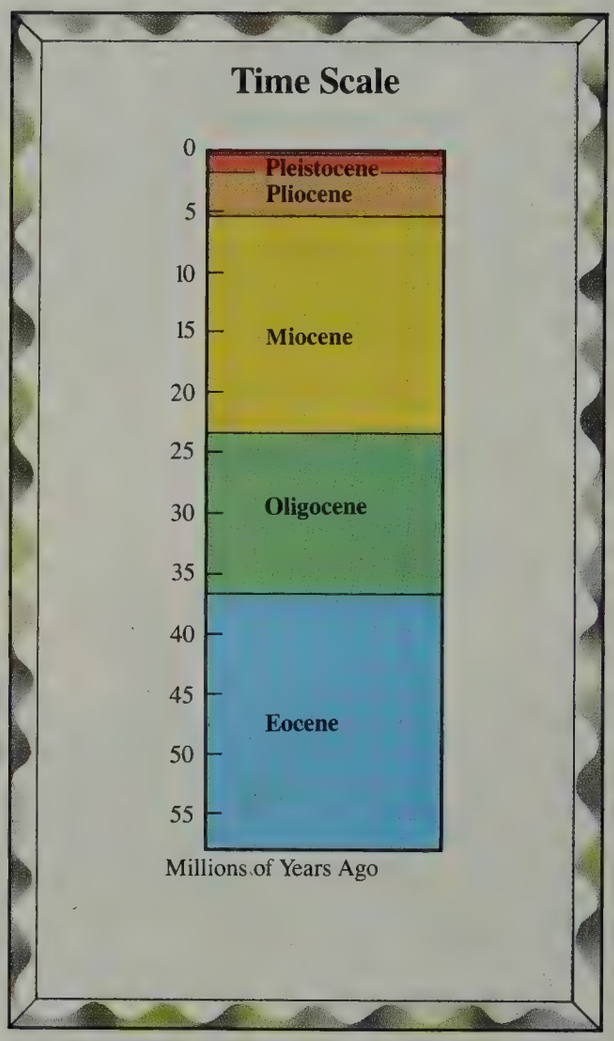
Sixteen Mediterranean islands (or former islands) have been found to contain fossils of endemic, or unique local, mammals. There are elephants on ten islands, deer on nine, hippos on four, and antelopelike bovids on two; most of these creatures are dwarfed. Another special feature of the fossil fauna of these islands is the absence of large predators, although there is a disproportionate number of birds of prey, especially owls. A few groups of small mammals (insectivores, such as shrews, and rodents) are also represented, and some of these species are larger than their mainland counterparts. Interestingly, similar "unbalanced" fossil fauna—limited to a few animal groups—occur on islands elsewhere in the world: the Japanese islands, the Philippines, the Lesser Sunda Islands, and the Channel Islands off California. When this large fossil record is taken into account, the land-bridge/degeneration hypothesis does not explain the consistent picture that emerges. Why did mainly the same mammals become isolated (deer, elephants, and hippos), and why do they often show the same trends in body structure?

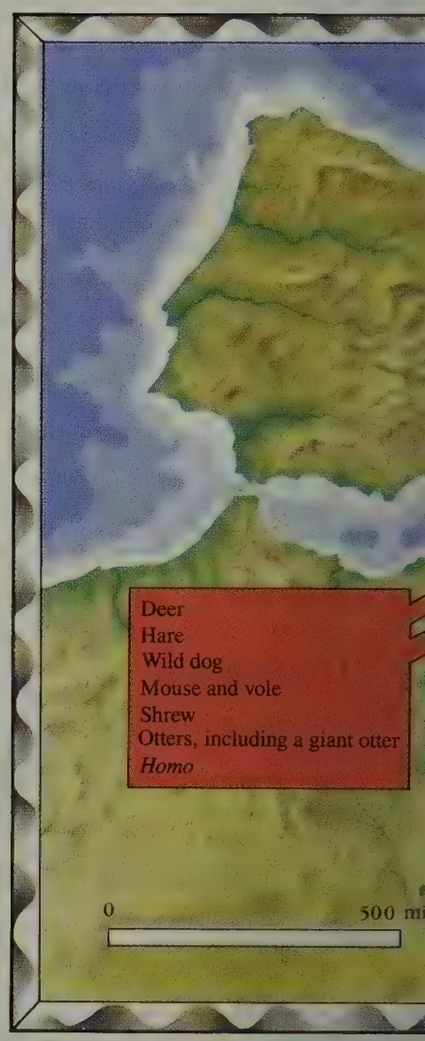
Good swimmers, elephants at times have colonized islands far from the mainland, leaving their descendants to evolve in relative isolation.

If we look at living elephants, deer, and hippos, however, we begin to see alternative explanations—all these land animals are excellent swimmers. Elephants love bathing, and there are numerous reports of them island hopping in the open sea off India and Sri Lanka (their trunks make excellent snorkels). Deer flee to water if they are in danger and have often been observed swimming. Hippos, which live in or near rivers, have been known to swim from the African mainland to the island of Zanzibar—a distance of more than twenty-three miles. Not noted for swimming long distances, rodents and insectivores are sometimes swept across water on natural rafts, such as floating mats of vegetation. All these creatures, then, can overcome a water barrier and reach islands without benefit of a land bridge.

If an island is close to the coast, animals that visit it remain in genetic contact with their parent population, by returning to the mainland themselves or because new arrivals periodically join the island inhabitants. In exceptional cases, however, owing to strong currents or stressful situations, animals may venture far from the coast, reach an isolated island from which they cannot return, and be forced to settle there. Such an event could be a chance occurrence or the outcome of special circumstances, such as a population increase. The late paleontologist George G. Simpson called this sweepstakes dispersal, meaning that the geographical route is impossible for most species and possible only on rare occasions for others. In most cases, dispersal on such a route is a one-way affair.

Sweepstakes dispersal explains—in a way that the land-bridge model does not—the limited selection of animal species found on the various Mediterranean islands. In addition, since islands populated by the sweepstakes route are by nature relatively isolated, the animals that settle on them are likely candidates to evolve into endemic species. Faunas with both of these characteristics (low diversity, endemic forms) can be easily recognized in fossil deposits even where a former island is now part of the mainland. For example, the northern Italian region of Tuscany was an island about 7 million years ago, with a monotonous fauna consisting of a few species of monkeys, some antelopelike bovids (including one with ever growing incisors), and a pig. Similarly, from roughly 20 to 6 million years ago, the present peninsula of Gargano, on Italy's Adriatic coast, was an island with its own unusual fauna—a five-horned ruminant closely related to deer, a giant hedgehog, and giant rodents.





Most of today's Mediterranean islands acquired their present form during the Pleistocene epoch (1.6 million to 12,500 years ago), and this is the period from which we have the most fossils of island fauna. Some of these places were once part of a mainland. Sicily was connected to Africa sometime late in the Miocene epoch (23.5 to 5.3 million years ago), as shown by fossil mammals of African origin found there. The region was submerged in the Pliocene epoch (5.3 to 1.6 million years ago) and then became an island, connected for a time with mainland Italy at the end of the Pleistocene. Similarly, Crete was part of mainland Europe for most of the Miocene, submerged near the end of the Miocene, and reappeared as an island during the Pleistocene. In contrast, on Majorca, Menorca, and Sardinia, island faunas appear without interruption as far back as the Eocene epoch (58 to 36.8 million years ago). These places seem to have remained isolated from the mainland even when, at the end of the Miocene, the Mediterranean is believed to have dried up (the so-called Messinian Event, caused by a temporary closing of the Strait of Gibraltar).

While each Mediterranean island has its own geological history, many were apparently populated by the sweepstakes route. The animals of a particular species

Often of dwarf size, elephants, deer, and hippos, along with other unique local species, once inhabited many Mediterranean islands. As shown on the map, below, the animals that lived on widely separated islands were often similar, reflecting parallel events in the founding of island populations and their subsequent evolution. Each island has its own geological history, however, and may yield fossils of various ages. Gargano and Tuscany, for example, now both part of mainland Italy, were islands during the Miocene epoch, at which time they were populated by the animal species listed. Pleistocene-age species are shown for the other islands indicated on the map. On Sardinia, one set of island inhabitants was replaced by another during the Pleistocene. The more recent group included humans who were unlike their mainland contemporaries.
Joe LeMonnier

that arrived on an island constituted a founding group. Since these founders were few in number, they represented only a small sample of the genetic variation in the mainland population. No two islands would have had the same sample, with the result that the descendants would tend to vary in a random way from island to island. If inbreeding affected these populations, they would be apt to vary from each other to an even greater extent. Instead, we find that the elephants on the different islands, for example, all deviated in the same direction from the ancestral mainland form, which was related to the present-day Indian elephant.

This parallel development on various islands suggests that the island environments strongly determined how the founding populations evolved and that this was more than a process of degeneration. The island fossil species were the results of a repeated experiment in natural selection: the immigrants were compelled to adapt to similar conditions on the different islands, and the outcome was therefore also similar. Some trends—most notably the diminution in size—even held across species lines.

Careful consideration of the taxonomy, dating, and distribution of island dwarf species confirms that larger mainland forms were their ancestors. While the various Mediterranean dwarf hippos, for example, are close in size to the living Liberian hippo (the so-called pygmy hippo), they are not closely related to it. Geographically they are widely separated, and more important, the dwarf species and the Liberian hippo differ anatomically. The arrangement of the skull bones, which paleontologists use to distinguish different members of the hippo family, shows that the island dwarfs are more closely related to large hippos. The placement of the premolar teeth and the shape of the canines also point to the same conclusion. The Liberian hippo, on the other hand, is simply a small mainland form; its ancestors were also small.

Because of their large size, elephants and hippos did not have natural enemies on the mainland. On the Mediterranean islands, which were generally free of large predators, large size lost its significance, while small size may have been advantageous, offering greater mobility in what was generally a mountainous environment and, thus, better access to island food resources. The animals' smaller size also made it easier for them to keep cool (dwarf hippos, for example, did not have to spend the whole day in the water as their mainland ancestors did). Finally, small size permitted a larger population.

Island dwarf species commonly resem-

bled each other in having heavy limb bones. Smaller mammals normally have slender limb bones, indicative of fleetness, but the island dwarf species have heavily built legs with shortened lower parts. Because there were no big carnivores on the islands, speed was no longer a necessary requirement for survival, while solidly constructed feet provided a useful "low gear" locomotion.

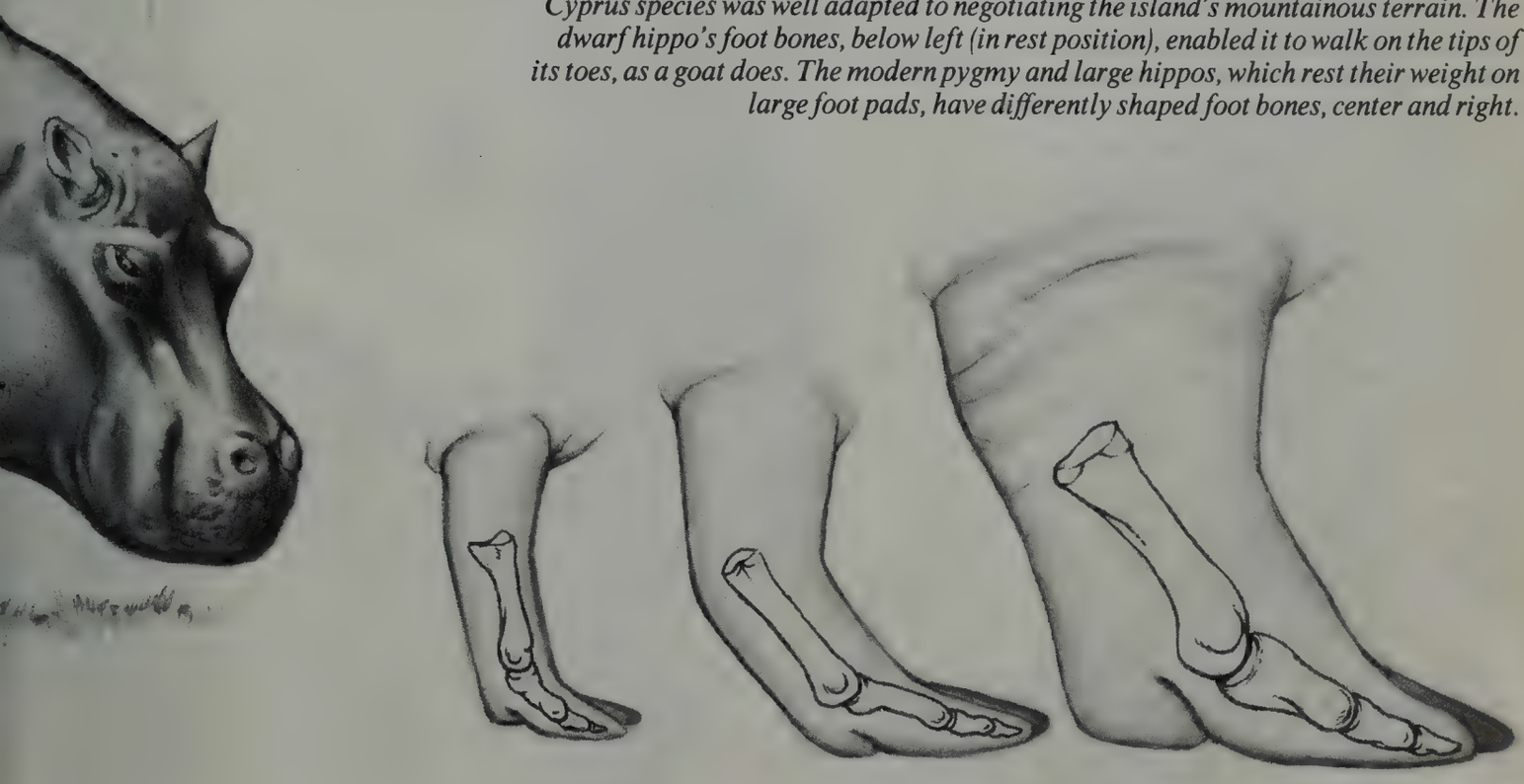
The phalanges, or toe bones, of the hippos on Crete and Cyprus, for example, are much shorter than those in the large hippo, and their articulation surfaces are different. In the large hippo, the phalanges support a large foot cushion; but the island hippos apparently lost their foot pads and walked on the tips of their toes, more like goats. This type of locomotion is unique in the hippo family and shows a major adaptational shift. These dwarf forms could have walked very well in mountainous regions—and the location of fossil finds shows that they did.

Paleontologist Gerard Willemsen recently studied the anatomy of present-day reindeer from the island of Spitsbergen, and he found clear parallels with the fossil deer and other ruminants of the Mediterranean islands: they are small and have relatively short legs. The reindeer on Spitsbergen have no natural enemies (even the polar bear does not hunt them), so they do not have to be fast runners. Instead, their short legs give them better stability in the rugged environment. After the brief summer season, they are extremely fat and heavy, having stored up extra food for the winter. Thus their short legs are also probably an adaptation to carrying this extra seasonal weight. Similar explanations may apply to the heavily built dwarf ruminants on the Mediterranean islands.

On the islands, we sometimes find evidence of mass starvation. The fossils occur mainly in caves and fissures where the animals sought shelter and died or into which their remains were washed. On Crete, in a small cave near Rethymnon, I found evidence of an ancient drama: the remains of more than a hundred individuals of a small endemic deer species, *Candiacervus ropalophorus*. The animals were mainly newborns, one-year-olds, or very old individuals. This age distribution suggests that they all died about the same time, probably in a bad season, and that only the strongest adults survived. A cliff on Cyprus (called Dragon Mountain by the local residents because of the fossils found there) is another example of a rich bone bed—in this case not a cave but perhaps part of a small river or pool. Its deposit of dwarf hippo bones seems to be the result of one event, pointing to a mass starvation. Fossils of endemic deer found there, as well as at a locality on Crete, show osteoporosis, a bone defect caused by chronic malnutrition. This type of evidence suggests that overpopulation, followed by food shortage, was the principal selective pressure on the islands. The absence of carnivores probably allowed herbivore populations to grow out of balance with the environment, causing overgrazing and destruction of otherwise suitable habitats. This may have been a recurring phenomenon, causing drastic changes in population size and thus favoring a quick rate of evolution.

Along with the islands' rugged terrain, such conditions account fairly well for the evolution of the short-legged, heavily built dwarf species found on the islands. The other endemic species that evolved may represent more complex adaptations to

A dwarf hippo, far left, was among the mammals that inhabited Cyprus in Pleistocene times. The arrangement of its skull bones and other details of its anatomy show that this species must have descended from mainland hippos similar to the large modern hippo, left. Despite a superficial resemblance, the modern "pygmy" hippo, foreground, a mainland animal from Liberia, is not a close relative. Because of its small size, the Cyprus species was well adapted to negotiating the island's mountainous terrain. The dwarf hippo's foot bones, below left (in rest position), enabled it to walk on the tips of its toes, as a goat does. The modern pygmy and large hippos, which rest their weight on large foot pads, have differently shaped foot bones, center and right.



these island environments. On Crete, for example, in addition to several species of dwarf deer, there were some of normal size and one large deer with long, slender legs, which probably had a giraffelike way of life. The variety of deer species was possible, in part, because of the absence of competition from most mainland animal species. Oversized rodents and insectivores, on the other hand, may have evolved because their large size afforded them protection against birds of prey, which were the only dangerous carnivores on the islands.

One curiosity is that on Sardinia (and probably also on nearby Corsica, although there is less fossil evidence from that island) a drastic change occurred in the middle Pleistocene. About one million years ago, an assortment of animals, including macaques, a small pig, and an antelopelike bovid, was replaced by a new group dominated by a deer, a small hare, and a dholelike dog. This second fauna of Sardinia is endemic and unbalanced, showing that Sardinia remained an island, but the deer is of mainland proportions. To learn why, in 1982 I, along with other paleontologists from Utrecht University, excavated an ancient cave once used for human habitation. (Its last occupant had been a Robin Hood-like bandit, who had lived there for twenty years until he was shot by the carabinieri in 1900.) When we dug down to the cave's Pleistocene sediment we saw unexpected accumulations of deer bones. The fossils were arranged in an unusual way and showed all kinds of cuts and grooves that could not be explained by natural causes. The discovery, in 1983, of a human temporal bone in the same sediment put an end to any doubt we may have had: humans must have lived in the Pleistocene island environment of Sardinia and preyed on the deer.

In 1985 we found more human fossils (an upper jaw and an ulna, the larger bone of the forearm), three flint scrapers, and small, curious pieces of animal bone. These last, which we consider to be artifacts, were all made from the same part of a deer ulna. Carbon-14 assessment puts the age of these finds at about 14,000 years. The possibility that these people, like other island species, were endemic to Sardinia needs to be studied; the fossils show that they were anatomically different from contemporaneous humans from the mainland. In northern Sardinia, Italian archeologists found a paleolithic tool industry of a type different from the mainland. This evidence, provisionally estimated to be about 200,000 years old, points to a long human occupation of Sardinia. The arrival of these people might have caused the extinction of Sardinia's earlier island fauna, and their presence there was almost certainly the reason why the deer did not lose their mainland proportions.

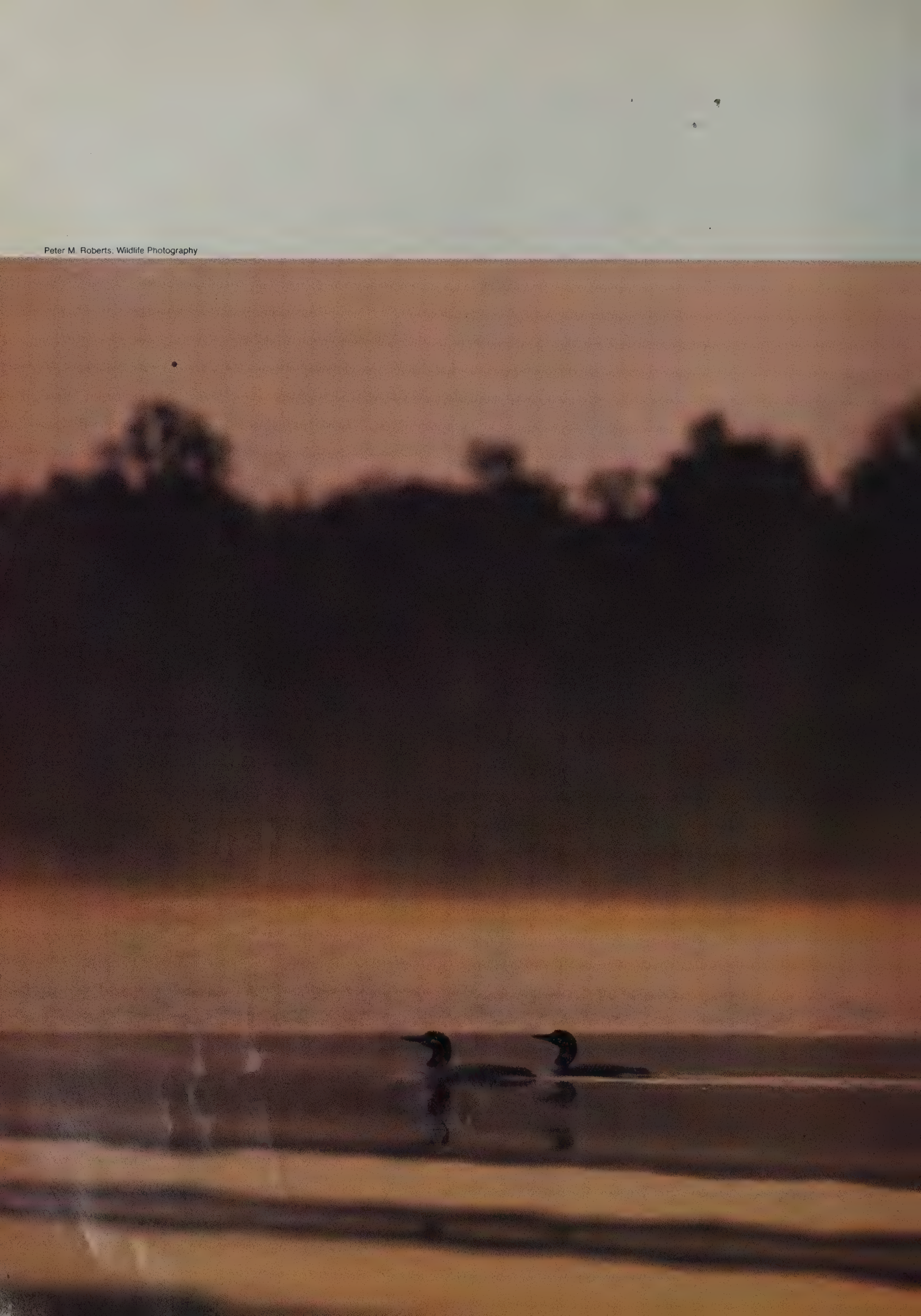
The early human colonization of Sardinia is an exceptional case among the Mediterranean islands. (Discoveries at Franchthi Cave, on the southern Greek mainland, show that people traveled to Melos about 9,500 years ago to collect obsidian, but they did not settle there.) Continuous human settlement was generally not possible on the islands before the advent of agriculture and animal husbandry. While dwarf elephants, deer, and hippos would have been easy prey for paleolithic hunters, the reproductive rate of these mammals is low, and hunting would have quickly reduced or exterminated them. Small rodents with a high reproductive rate were present on most of the is-

lands, but they were probably too small to provide sufficient protein. As a result, no ecological equilibrium could have been established. A reasonably large mammal with a high rate of reproduction seems to be an essential resource to support a permanent hunting population. The larger hares of Pleistocene Sardinia may have fulfilled this requirement and, along with the island's size and position not too far from the mainland, rendered Sardinia the only island in the Mediterranean suitable for permanent colonization by paleolithic humans.

With the exception of Sardinia (and possibly Corsica), humans moved relatively recently onto the Mediterranean islands. The larger islands like Cyprus, Crete, and Sardinia were colonized about 8,000 years ago by neolithic humans, who brought their sheep, agriculture, and pottery and drastically changed the life on the islands. The arrival of neolithic humans was followed by the extinction of all surviving Pleistocene island endemic types (including, perhaps, a remnant paleolithic human population on Sardinia). Nikos Symeonidis of Athens University has learned that dwarf elephants were still living on the Greek island of Tilos 7,000 years ago, and neolithic people were using their ivory.

Neolithic humans should not be held entirely responsible for the extinctions. Environmental factors also played a role. The fluctuation of the Pleistocene glaciers caused drastic changes in sea level. When the glaciers melted and the sea level rose, islands may have become too small to supply enough food for a population of mammals. On the other hand, during periods when sea water was trapped in glaciers, islands might have become connected with the mainland—this happened to Sicily at the end of the Pleistocene. Once an island became connected with the mainland, its endemic mammals would have had no chance of surviving since they were easy prey for the large mainland predators. In many cases, however, human population of the islands must have dealt a final blow, and the peculiar mammals vanished, leaving only fossils as a trace of their existence. □

The fossils of at least seven species of deer have been found on Crete. They ranged from dwarf forms to two of normal size to one that was taller than any known mainland deer. The tall deer may have exploited its habitat much the way a giraffe does. The absence of dangerous carnivores apparently allowed these species to exhibit unusual combinations of size and proportion. Small mainland animals, for example, typically have slender limbs, indicative of fleetness. The island dwarfs, however, had sturdy, shortened limbs, reminiscent of those of large mainland creatures. Conversely, the tall deer on Crete had slender limbs, giving it the proportions of a small mainland animal.


Peter M. Roberts, Wildlife Photography

Lost Loons of the Northern Lakes

The young birds are hapless victims of lake acidification

by Robert Alvo

Many visitors to the lake country of the northern United States and southern Canada have glimpsed the highly contrasting black-and-white breeding plumage of the common loon. Its lonesome wail, delivered in the small hours of the morning, is as much a part of the wilderness experience as portaging through clouds of black flies. The cottagers who live in these regions often talk of "our pair of loons," and many people believe—and there is beginning to be good evidence for their conviction—that loons mate for life and return to the same lake year after year.

Whether or not they return to the same sites to breed, loons return each spring to an increasingly hostile environment. Along with many other man-made threats to their survival—including harassment by boaters, loss of nest sites through the building of cottages, and mercury poisoning on their wintering grounds—increasing acidification of northern lakes now threatens loon populations.

Acid rain is subduing lakes in a most subtle way, causing the virtually unnoticed dissolution of these aquatic ecosystems until they finally collapse. The process starts as the oxides of sulfur and nitrogen—byproducts of ore smelting, coal burning, and the combustion of other fossil fuels—are lifted high into the atmosphere, where, transformed into deadly sulfuric and nitric acids, they may travel thousands of miles (see "The Acid Rain Whodunit," *Natural History*, July 1986). Returning to the earth in rain, snow, or dust, a good proportion of these acids find their way into streams, ponds, and lakes. Some lakes can withstand inputs of acids for many years because they sit in or near beds of limestone, but lakes that are not blessed with the acid-neutralizing virtues of limestone can lose their fish populations in just a few years.

A striking paradox is the majestic beauty of many acidic lakes—the water is a clear, deep oceanic blue, not unlike what one would expect to find at a remote tropical beach. It is inviting to the bather, and its fresh clean taste is attributable to the scarcity of plankton, the microscopic plants and animals that are the basis of the aquatic food chain. Viewed from within, these lakes offer the skin diver a ghostly landscape in which rocks and fallen trees are covered by a carpet of threadlike algae, one of the only forms of life that thrive in the altered chemistry. If the diver searches long enough, he may find the odd dragonfly nymph clinging to a rock, possibly the last of its kind to eke out an existence there. A hiker who returns to a campsite after two weeks finds that the grains of rice that had settled to the bottom while he was washing dishes in the lake still lie there untouched. Paddling near an island, a canoeist can peer down forty feet through the crystal clear depths and see no movement other than the shadow of his craft.

The devastating effects of lake and stream acidification on fish were first noticed in Norway in the 1920s, but little concern was shown until the 1960s, when a number of lakes in Norway and Sweden were found to have lost many of their fish. Not until 1972, however, when University of Toronto zoologists Richard Beamish and Harold Harvey published their classic paper on the loss of fish from a number of acidic lakes in the La Cloche Mountains of Ontario, was the problem widely acknowledged on this side of the Atlantic. On one lake eight species of fish were lost over a period of ten years, as the acidity of the lake changed from pH 6.8 to 4.4. (Water with a pH of 7 is considered neutral; pH 0–7 is acid; 7–14 alkaline.)

During the next fourteen years, scientists conducted a number of aquatic surveys, as well as laboratory and field experiments, and found that eggs, larvae, and fingerlings were more sensitive to acid than were adult fish, which seemed to be sensitive only to heavily acidified water. Animal and plant plankton, aquatic insects, crayfish, and frogs were also found to be sensitive to acid stress.

In a long-term study published last year, David Schindler and co-workers at Canada's Department of Fisheries and Oceans experimentally acidified a lake while monitoring living things at various levels of the food chain, excluding birds. They discovered that a reduction of pH from 6.8 to 5.0 over eight years caused a number of drastic changes, including the

cessation of fish reproduction at pH 5.4.

Although scientists do not always agree on the order in which species disappear from lakes or at what level of acidity certain changes occur, they do agree that once lakes become heavily acidified, they are markedly—perhaps irreversibly—damaged. Researchers generally agree that aquatic birds are probably also being affected, but this aspect of the problem has been largely ignored until recently.

I thought common loons would be appropriate birds to study because of their dependence on lakes during the breeding season. They nest on the shores of lakes and are opportunistic feeders, devouring fish, amphibians, crustaceans and other freshwater and marine invertebrates, as well as vegetation. Loons are primarily fish-eaters; they need an expanse of open water in which to feed and a sheltered nest site with a deep approach area. Lakes smaller than 120 acres are usually defended by only one pair, while larger lakes are often partitioned by several pairs.

Loons prefer to nest on islands, protected from raccoons, skunks, and minks; but when islands are not available, the birds usually select marshy areas of lakes. Located far back on the body, the loons' legs give them great underwater mobility, but the birds are very clumsy on land and would have difficulty clambering up to nests far from the shore. They therefore nest right next to the water's edge. During the roughly twenty-eight-day incubation period, parents take turns sitting on their two eggs. The chicks venture out of the nest into the water usually within a day of hatching. For the following two weeks the young are vulnerable to cold, fatigue, and predation by pike, turtles, eagles, and gulls. Most importantly, for about eleven weeks—until they learn to fly—young loons are restricted to their natal lake and must live on food found in its waters. This period of confinement makes it easier to assess the breeding success of loons, for

Dennis W. Schmidt; Valan Photos

A parent takes its turn tending the nest, left, during the 27- to 28-day incubation period. Ungainly on land, loons nest as close as possible to the water's edge and favor protected sites on small islands in lakes. The precocious loon chick will abandon its nest, below, and begin life on the water within a day of hatching.

Peter M. Roberts; Wildlife Photography

unlike many other water birds, the young cannot travel overland to feed at other lakes and ponds.

In 1982, I began what was to be a four-year study of the effects of lake acidification on loon breeding success. In the first year, I surveyed eighty-four lakes near Sudbury, Ontario, to see whether there was a noticeable difference in loon breeding success on acidic and nonacidic lakes. This part of the province has some of the most acidic lakes in North America, with pH levels as low as 4.0; yet there are also a number of healthy lakes nearby. Although the healthy lakes also receive large inputs of acid, they are protected—at least temporarily—by the neutralizing effect of the dissolved limestone from surrounding soil.

Of the original eighty-four lakes that I surveyed in 1982, I eliminated from my analyses the sixteen that were smaller than the smallest lake on which loons nested (thirteen acres). Although unmated loons used most of these lakes, probably for snack stopovers, the habitats were too small for breeding pairs. In 1983 and 1984, I surveyed only lakes with breeding pairs. Overall, in the first three years of my study, I monitored a total of fifty-two pairs of loons, each with a brood of one or two chicks.

I started making my first visits to the lakes during the latter half of June, when loons were starting to nest. Usually accompanied by an assistant, I drove from lake to lake. At each lake we first paddled along the shoreline in search of a loon's nest. Then we paddled out to the center of the lake to collect a water sample, which we analyzed, often by the light of a gas lamp, when we returned to our campsite. In September, we made attempts to determine whether there were still young on the lakes. To ascertain whether pairs were successful in raising young, I always revisited the lakes just before the young were ready to begin flying. As long as the young were not already fledged and were still alive, I knew that they had to be on the natal lake. And since I had selected lakes that were large enough for only one pair of loons, there was no chance of confusing the young of different pairs.

The task was still difficult because, unlike loons that live on cottage lakes and grow accustomed to humans, loons on my remote study lakes usually fled or hid at the first sight of our approach. Sometimes the young moved to shore, where they would remain inconspicuous among the bushes; other times they would dive repeatedly, periodically poking their periscopelike bills through the surface and inhaling a breath of air before sinking again to the safety of the depths.

Unconvinced of the absence of young loons on some lakes on which the loud vocal behavior of the adults indicated their presence, we sometimes took a land approach. Parking some distance from the lake, we crept to the shore through the woods. By this means we usually located the young, but the first snap of a twig in our path often alerted the adults to our presence, and the young would disappear.

After my first field season, I found that proportionately more healthy lakes had successful breeding pairs than did acidic lakes. This was not because loons were avoiding acidic lakes for breeding or be-

Peter M. Roberts; Wildlife Photography

Below: A loon "dances" on a lake to draw attention from its nearby nest. Very young loons are often ferried about by an adult, right. Chicks closely attended by parents have a better chance of eluding gulls, turtles, and pike, which prey on hatchlings.

Tom W. Parkin; Valan Photos

cause females were laying fewer eggs or even that eggs were failing to hatch. Rather, the data collected over three years showed that loons breeding on these lakes were losing their young. Although other researchers have found that, in general, brood mortalities rarely occur after chicks reach the age of two weeks, of the fourteen cases of brood mortalities I observed, several seemed to be taking place after this point. I recorded three such cases directly and had indirect evidence that the young in six other instances had also died after the normal vulnerable phase in their development. Most of these late brood deaths occurred in the acidic lakes. Because I did not visit each lake every day, I could only estimate chick age. In some instances, I never saw the chicks because they had died before my visit; however, I knew that eggs had hatched because I discovered one or two egg membrane sacs on the nest.

Ultimately, I found that 62 percent of the broods on the acidic lakes died, while on the healthy lakes only 14 percent died. Intermediate lakes lost only 20 percent of the broods. Was the loss of fish on the acidic lakes responsible for the low survival rate? Were pairs that once bred successfully on these lakes unable to overcome the ingrained behavior of nesting on the same, now severely acidified lake year after year?

Caring for loon chicks requires much devotion by the parents. They spend many hours every day diving and coming up with single morsels of food, which they ferry along the surface to the waiting young. The family generally cruises along the shoreline, using the whole territory or lake to feed. During the first few weeks the young are fed plant material, crayfish, aquatic insects, leeches, and fish, the percentage of fish increasing as the young grow. The young make short dives and bring up some vegetation and insects on their own. As they grow older and lose their downy plumage, they become increasingly skillful at capturing fish. The parents generally feed on the natal lake, especially during the first few weeks, when the young are still dependent.

Perhaps I could find out if a shortage of food was causing the brood mortalities on the acidic lakes by observing the parents feeding their young. In 1983 and 1984, I planned to observe loon families from the shores of several healthy lakes and several acidic lakes to find out whether the parents were able to supply the chicks with enough food. But the chicks were not surviving very long on the acidic lakes, and on a number of lakes, the loons were easily disturbed by my presence. Nevertheless, I was able to make observations on two healthy lakes and on two lakes that were somewhat acidified but not totally devoid of fish. I wasn't able to establish anything definitive, but what I did find out was suggestive.

Fish caught by loons for their young were often visible through my spotting scope because they were relatively large, but some of the food items—probably aquatic insects or bits of vegetation—were tiny. During the first month of life, chicks were fed very small food items and small fish; but later they were fed mostly fish. During the latter stage, the parents on the somewhat acidified lakes had to dive more frequently than the parents on the healthy lakes to capture the same number of fish. While the fish population was probably more dense on the healthy

lakes, differences in species or size of fish may also have been a factor. (No one has yet undertaken the immense task of measuring the fish populations in these lakes.)

Still not convinced that the chick mortalities I was documenting on the acidic lakes were due to a shortage of food, I resolved in 1985 to find a family of loons on one of the acidic lakes and to make detailed observations before the young died. For three breeding seasons, a pair of loons on acidic Marjorie Lake (possibly the same pair every year) had lost their sole chick when it was several weeks old. Based on my own sampling and that of others, Marjorie lake was not only fishless but was probably also devoid of crayfish, frogs, and aquatic insects. The bottom of the lake was covered with a dense mat of filamentous algae. I observed the loons on Marjorie Lake for three days to learn what the parents were feeding the chick and what they themselves were eating.

Only thirty-four miles northeast of the city of Sudbury as the loon flies, Marjorie Lake could be hundreds of miles from civilization. Unless one flies in, the quickest way to get there is to drive forty-four miles along an old logging road that winds through dying forest (in which the last deer was seen fifteen years ago) and past sterile lakes that somehow still manage to attract fishermen. To get to the lake I always parked at the side of the road and paddled through two other lakes. During the years that I visited the lake, the only other parties I encountered were a pair of scientists studying the acidification of a neighboring wetland and two unknowing fishermen who had flown in.

Marjorie Lake is tailor-made for two pairs of loons. Its 185 acres are divided into two large roundish bays, each with several small islands and suitable for one pair. Yet I never saw more than one pair there, and a number of nearby lakes that also could have had breeding loons did not. There were no frogs breaking the summer's silence, no fish rippling the water's surface at dusk, and only a few songbirds voicing their territorial ownership. On rare occasions I saw hooded merganser hens accompanied by unusually small broods of ducklings.

During my 1985 visit to Marjorie Lake, I sat behind cover for three days, at first about half a mile away from the loons, and watched through my spotting scope. Later I found I could get to within about 700 feet of the family without disturbing them. Because they stayed in a small bay instead of cruising around the whole lake, they were almost never out of my view.

Peter M. Roberts; Wildlife Photography

Even on healthy lakes, loon hatchlings, like the one guarded by parents, below, are especially vulnerable to cold and predation during their first two weeks of life. A young loon, right, flexes its wings, but it cannot leave the lake on which it was born until it fledges at about eleven weeks.

Tom W. Parkin; Valan Photos

They knew I was there but were content as long as I kept my distance.

I observed a number of things on Marjorie Lake that differed sharply from what I had seen on several healthy lakes with loon families. For one thing, when the parents dived, either singly or together, they fed the chick virtually every time. Their rate of success made me suspect that they were not finding fish, since my observations on two healthy lakes showed that when the parents were securing vegetation and insects for the young, they surfaced with food after 70 percent of the dives. When they were chasing after fish, however, which are more difficult to capture, their feeding success rate fell to 23 percent. But on Marjorie Lake, the parent loons were coming up with something to feed their chick 97 percent of the time. The food was obviously easy for them to catch, and although I usually could not identify the food because the pieces were so small, I postulated that it was algae from the lake bottom, which possibly contained some small insects. Sometimes I could even discern small strands of what looked like algae hanging from the bill. The chick was evidently not receiving fish, as these would have been readily identifiable through my spotting scope.

I never saw either parent go off on its own to forage in a different part of the lake, as adult loons usually do. The parents simply did not seem to be feeding themselves on Marjorie Lake. Instead, one would fly away from the lake, something that loons rarely do when their chicks are so young, while the other remained behind. The loon would return several hours later, probably having fed elsewhere, and greet its mate with a wing flap and a tremolo. After a session of feeding the chick, one of the parents, presumably the one that had stayed on the lake earlier, would fly from the lake and return several hours later. I never saw either parent fly back to Marjorie Lake with food for the chick—unlike many red-throated loons, which nest not far inland and make several flights daily from small ponds to the nearby ocean and return with one fish per trip for their brood.

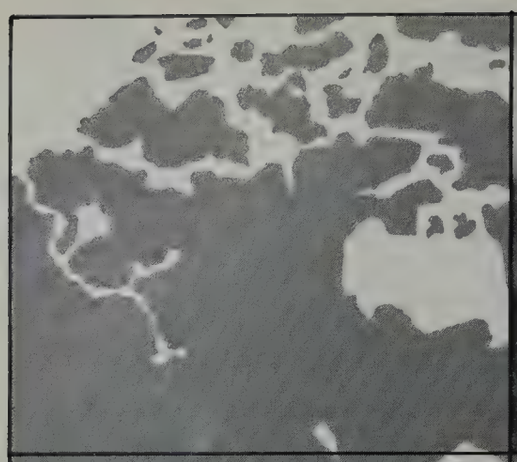
Often I could see the chick by itself close to the shore, sometimes among the bushes hanging over the water. While paddling forward, it would stretch its neck toward something on the surface, manipulate it in its bill, and then make violent gulping motions. It may have been catching whirligig beetles, which congregated on the surface in small sheltered areas near the shore. On one occasion, the chick even clambered onto a rock onshore in pursuit of something, then quickly returned to the water. Considering the amount of time the chick spent feeding itself—a great deal compared to chicks on other lakes—I hypothesized that beetles were making a significant contribution to the chick's diet. Whether or not the quality and quantity of the food that the chick was obtaining from its parents and through its own efforts would satisfy its daily nutritional requirements remained to be seen.

When the chick was not being fed by the parents or capturing its own food, it spent a great deal of time riding on the back of one of its parents, something common among chicks less than three weeks old. But instead of sitting upright in the usual fashion, this chick often lay on its belly at the posterior end of its parent, with its feet dangling in the water. Was this a sign that the chick was starving?

Atypically, the loons never left a small bay at the south end of the lake, except when one of the adults flew from the lake. Did the lack of fish reduce the need for the adults to comb more of the shoreline? The only available food—filamentous algae and possibly small invertebrates in the algal mat—was ubiquitous and stationary, and the loons therefore did not have to seek out new areas that they had not already exploited.

One way to positively identify the food the chick had eaten would have been to analyse its stomach contents. Although I was convinced that this chick would soon perish because its increasing need for fish was not being met, I would never know for certain unless I allowed it to die in its own time. Even if I could obtain a permit to capture a baby loon and sacrifice its life for science, could I bring myself to end those six weeks of defending a territory, constructing a nest, and incubating and caring for the chick? Would it be fair not to give the chick a fighting chance? I finally decided to let the loons determine their own fate, and I left Marjorie Lake.

Two weeks later I returned to the now loonless lake. Even if the loons return during the next few years, they will have no chance of breeding success. Marjorie Lake is truly dead. □



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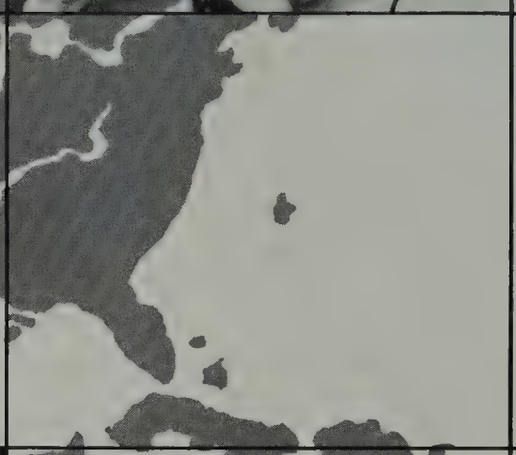

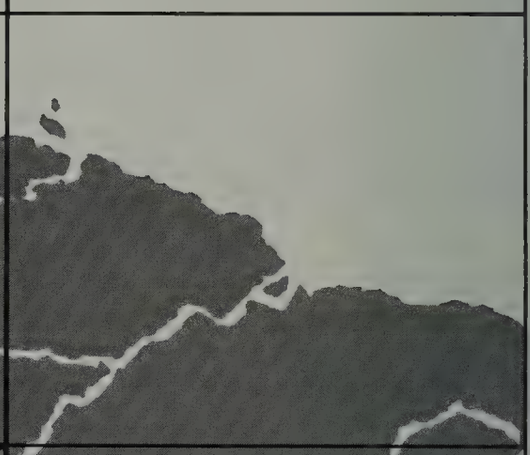

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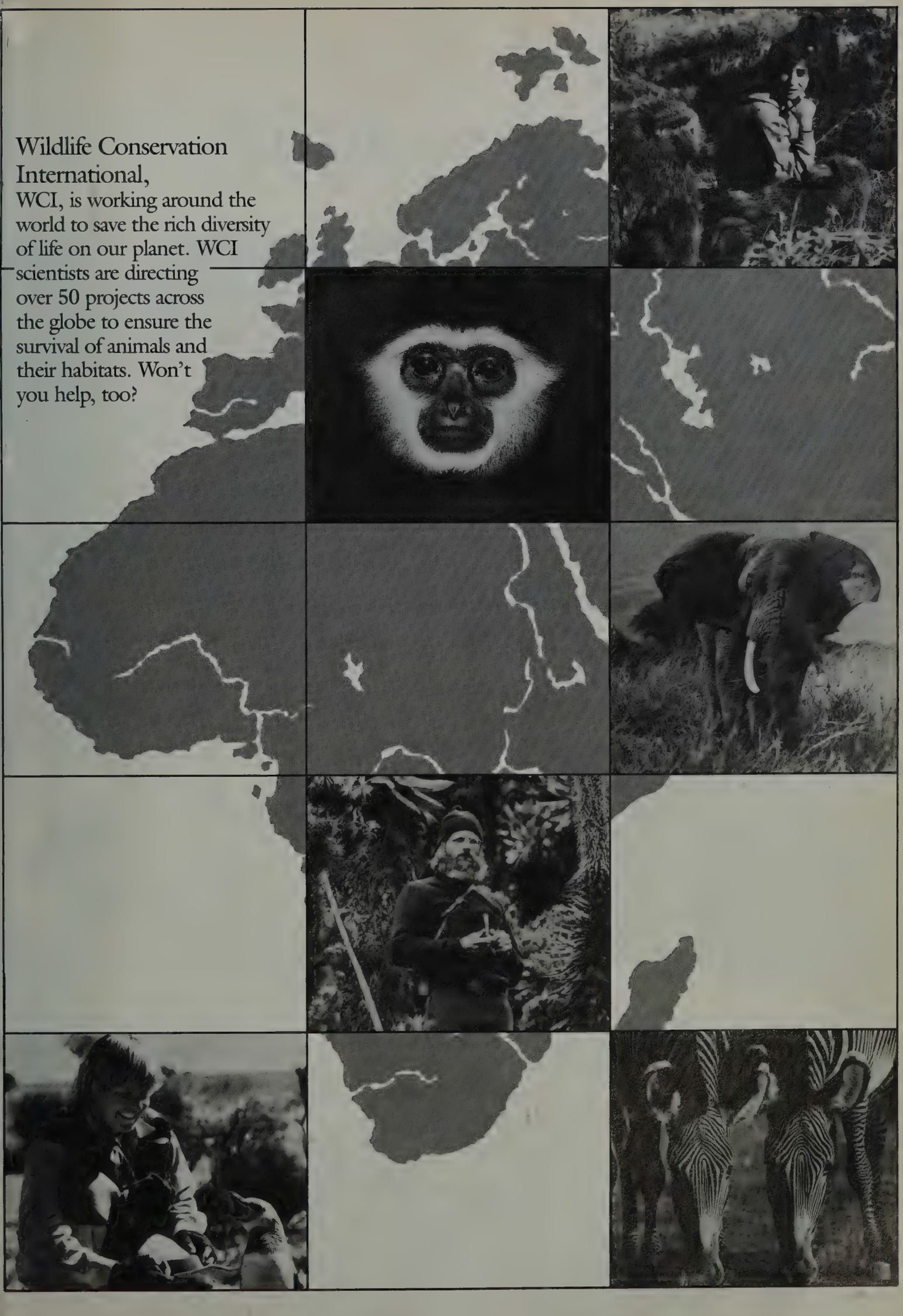
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Sky Bridge is the largest natural rock arch in the Red River Gorge.
David Muench

Red River Gorge, Kentucky

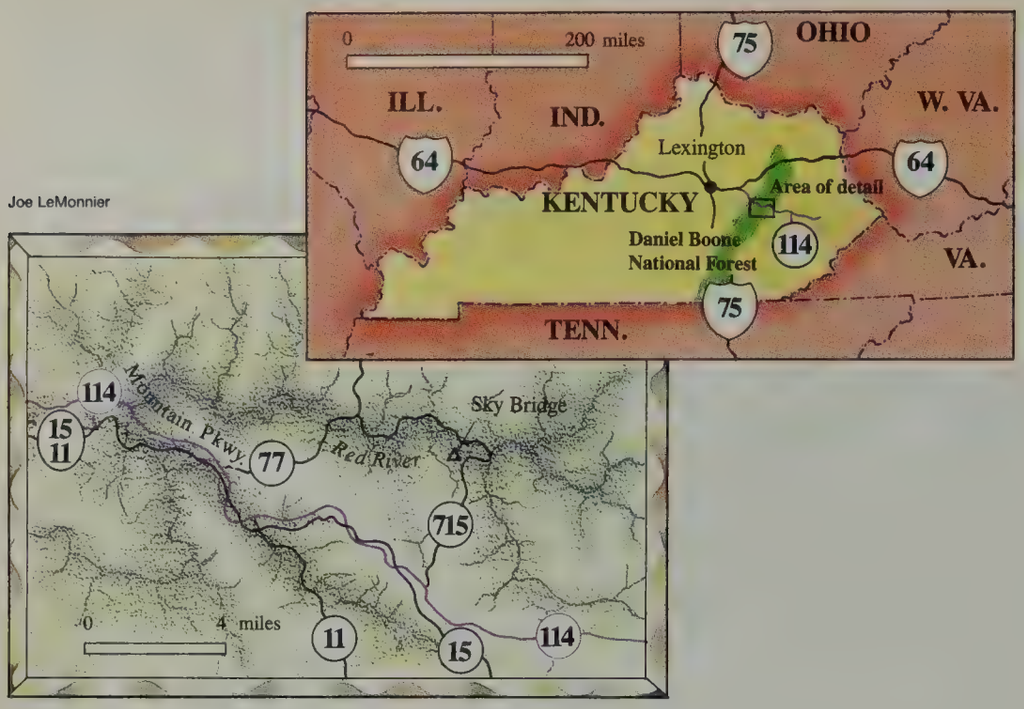
by Robert H. Mohlenbrock

Except for the Canyonlands and Arches areas of the Colorado River drainage in Utah, no part of the country boasts as many natural stone arches as Red River Gorge, the focal point of Daniel Boone National Forest. At least 100 arches carved by erosion dot the forest lands, which lie some fifty miles southeast of Lexington, Kentucky. Of modest size, and often obscured by the surrounding foliage, these features look like the abandoned bridges of some overgrown garden. Drama on a greater scale is provided by vertical cliffs that rise as much as 600 feet above the twisting Red River.

The foundation for the rocky gorge was laid 300 million years ago, as shallow seas, swamps, and rivers covered the region a number of times. At times, water deposited a lime-bearing ooze; at other times a clay-rich mud accumulated or sand washed up along ancient shores and streams. As new layers were added, these sediments were compressed into rock, the lime-rich ooze turning into limestone, the clay-rich mud becoming shale, and the sandy deposits forming sandstone. In most regions the earliest strata consist of limestone, while the sandstone lies above.

After these sedimentary rocks had formed, a twisting of the earth's crust caused a domelike uplift from southern Ohio through central Kentucky. Following the uplift, the Red River and its tributaries began their erosive action, cutting through the hard sandstone into the softer rocks below. Today the landscape is deeply dissected by valleys rimmed by sandstone bluffs and ridgetops.

According to Kentucky botanist and geologist A.C. McFarland, most of the arches of the Red River Gorge are the remains of sandstone ridgetops. As the softer shale and limestone below the sandstone erode away, large overhangs are left, creating what are known in Kentucky as rock houses. Sometimes two rock houses develop back-to-back under the same ridge. As erosion continues, the two rock houses may meet. At first, only a small opening known as a lighthouse is formed. In time, the lighthouse becomes a window and ultimately the opening of an arch. The most spectacular of the natural arches is



Joe LeMonnier

Red River Gorge

For visitor information write:
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called Sky Bridge: it measures seventy-four feet long and twenty-three feet high.

The vegetation in the Red River Gorge is varied. The ridgetops are dry, supporting a forest dominated by shortleaf, Virginia, and pitch pines; black, scarlet, white, and post oaks; shagbark hickory; and red maple. Downslope, where more moisture is available, beech, tulip poplar, basswood, and sugar maple are the primary trees. Eastern hemlock, a tree more common to the northern states, often grows on north-facing slopes.

The ancestors of most of these trees and other predominant plant species established themselves in the region 50 to 70 million years ago, but some additional species arrived during the last Ice Age (the Pleistocene epoch), which began 1.6 million years ago. When the Ice Age glaciers made their southern advance, stopping only 200 miles north of the Red River Gorge, the climate cooled, apparently permitting northern species to penetrate the area. Even after the glaciers receded and the temperatures moderated, some of these northern elements, such as false lily of the valley, small ginseng, purple fringed orchid, and Canada lily, persisted in sheltered ravines.

Similarly, several species from warmer regions reached the Red River Gorge when the Pleistocene climate was suitable for their spread. Among those usually associated with the southern Appalachian Mountains are pygmy pipes (a plant that lacks chlorophyll), spreading pogonia orchid, and the sweet pepper bush. The Georgia lobelia, a rare southern species, has also been discovered in the gorge's moist woods.

The plant in the Red River Gorge with the most restricted range is the white-hairy goldenrod, a species confined to a few of the rock houses. It is found nowhere else in the world, although there are similar-appearing sandstone overhangs in Indiana, Illinois, and Arkansas, as well as in other places in Kentucky. The white-hairy goldenrod was discovered in 1942 by E. Lucy Braun, a plant ecologist at the University of Cincinnati who devoted much of her life to analyzing the origin of the eastern deciduous forests. The origin of this particular plant remains a mystery. There is a less hairy goldenrod, called zigzag goldenrod, widespread in the Midwest, that sometimes grows in the same rock houses as the white-hairy goldenrod. Some botanists have suggested that this plant was the ancestor of the rare species.

The discovery of ancient arrowheads and spearpoints indicates that the Red River Gorge was occupied by humans beginning as early as 10,000 years ago. The deeper rock houses often provided shelter for these early inhabitants. Although the forest now receives thousands of visitors annually, so far most of its natural features have withstood human intrusion. The greatest threat to the region is a plan to build a huge reservoir, authorized by the federal government in 1962 but currently on hold, which may someday be reactivated. If this happens, the area will again be covered by water, as it was millions of years ago.

"This Land" highlights the biological phenomena of the 153 U.S. national forests. Robert H. Mohlenbrock is distinguished professor of botany at Southern Illinois University of Carbondale.

Don Fig; U.S. Forest Service

White-hairy goldenrod grows beneath some rock overhangs in the Red River Gorge, and nowhere else in the world.

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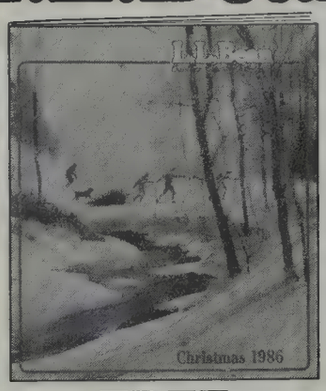

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In Search of the Woolly Mammoth

by John R. Alden

Few of us have not felt the lure of the Ice Age. And surely, one of the era's primary attractions is its remarkable bestiary. Woolly mammoth and rhinoceros, giant elk and bison, cave bears and dire wolves and saber-toothed tigers are all extinct, but they roam the landscape of our imagination as actively as they once wandered the ice-girt world of our paleolithic forebears.

ON THE TRACK OF ICE AGE MAMMALS, by Antony J. Sutcliffe. *Harvard University Press, $25; 224 pp., illus.*

These creatures have also attracted the attention of a panoply of sciences. Geologists use their remains as chronological markers. Archeologists and anthropologists study them for clues to early human adaptations. Biologists see their skeletons as evidence of evolutionary relationships. And for paleontologists, who occupy the center of this scientific web, Ice Age mammals provide one of the most important sources of evidence for reconstructing Quaternary environments and the ecology of Pleistocene life.

With this multidisciplinary tribe on the track of these creatures, it is hardly surprising that our understanding of them changes constantly. For the nonprofes-sional, however, the progress of this scien-

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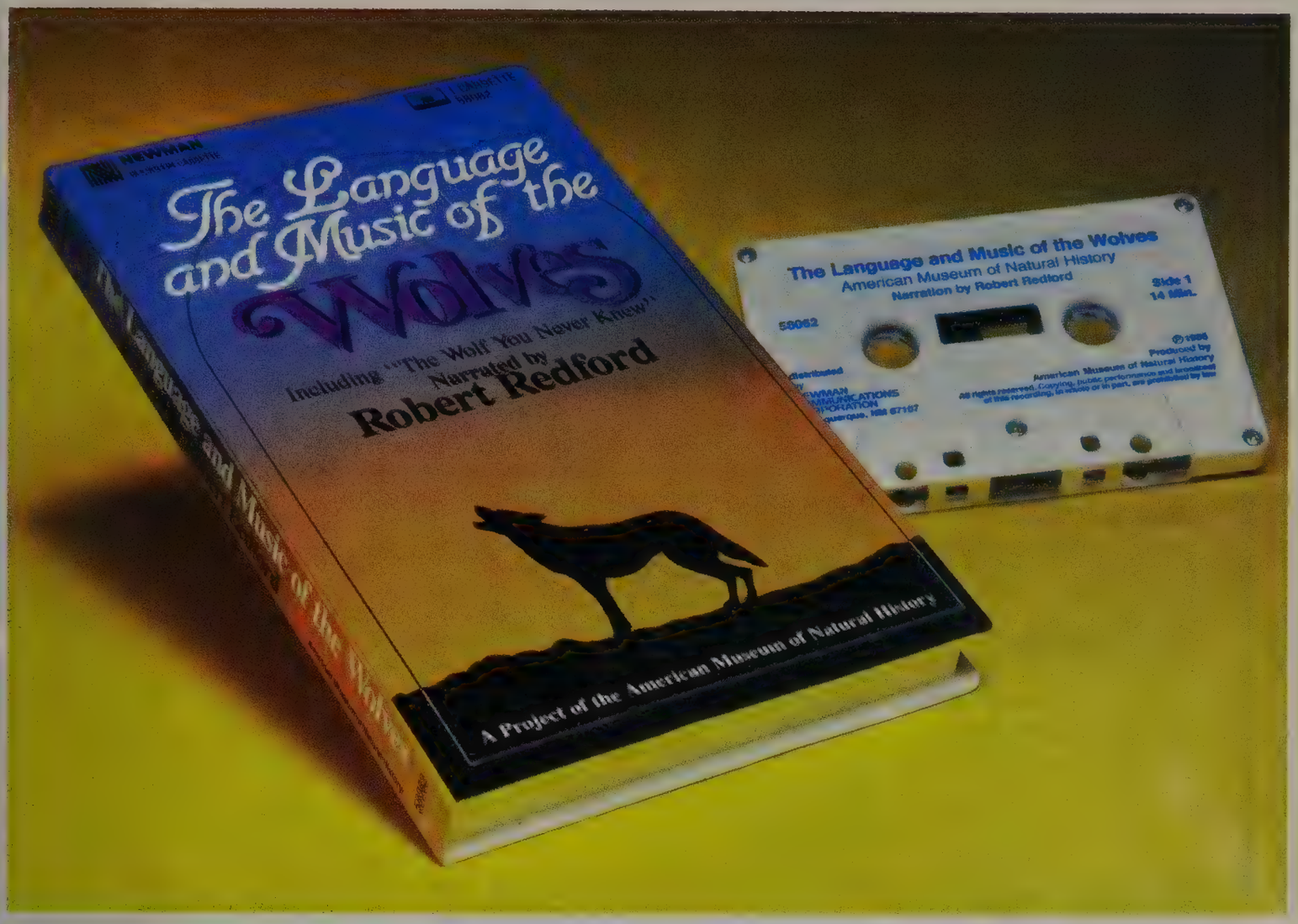
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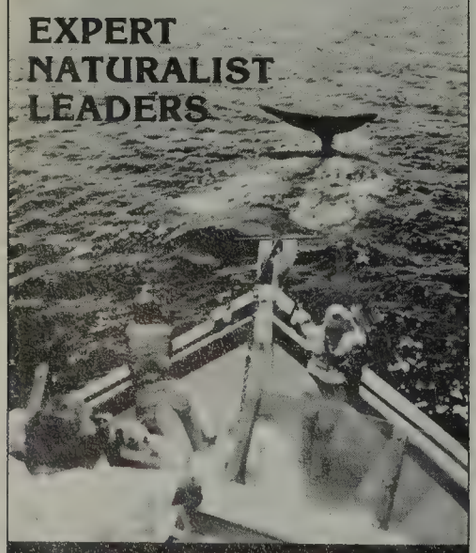
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Cave painting of spotted horses, Lot, France

tific process is hard to follow. Bits and pieces of recent research may reach the mass media, but without digging through academic journals and sitting through academic conferences, it is almost impossible for one to be really up to date. So interested amateurs will be pleased to know that a thorough, scholarly introduction to the study of Ice Age mammals has recently been published.

On the Track of Ice Age Mammals appears surprisingly slim, and a quick examination will reveal that nearly half the book is illustrations. But the clear, concise text is densely packed with useful information, while the numerous, carefully selected photographs, drawings, charts, graphs, and paintings are easily worth their weight in words. Because the book is intended for "the serious reader . . . who would like to be able to follow the way in which [paleontological] investigations are undertaken," it may prove a bit donnish for some. Enthusiasts, however, will revel in the author's explication of a complex and fascinating discipline.

The Ice Age began some two million years ago, when a confluence of geographical and astronomical features precipitated an ongoing series of glacial advances and retreats. As recently as two decades ago scientists spoke of four principal glaciations, but data from deep-sea cores now indicate there were at least seventeen major cold–warm cycles since this global phenomenon began.

The record of these climatic oscillations is read in the ratios of oxygen isotopes from the shells of tiny sea creatures called foraminifera. During colder periods more "light" water (water containing the lighter isotope of oxygen, oxygen^{16}, which evaporates more readily than water containing the heavier oxygen^{18}) was tied up in glacial ice, causing the proportion of oxygen^{18} in calcareous shells to increase.

During the warmer interglacials, the pattern reversed. The oxygen isotope data are complicated by a variety of other factors, including the prevailing water temperature and, in places like the Gulf of Mexico, changes in the flow of glacial meltwater from the continental ice sheets. But because cores from the Pacific, Atlantic, and Indian oceans all show the same relative sequence, there is little doubt that the variations recorded in these microscopic shells accurately reflect the spreading and shrinking of vast expanses of glacial ice.

The climatic fluctuations the earth has experienced over the last two million years were hardly minor. Only 18,000 years ago, so much water was tied up as ice that worldwide sea levels were approximately 300 feet lower than they are today. At the other extreme, during one relatively recent interglacial the oceans were some 75 feet higher than they are now. Patterns of air and ocean circulation have also varied, bringing dramatic changes to areas far from the northern ice. At the height of the most recent glaciation, Sutcliffe tells us, nearly half of the land between thirty degrees north and thirty degrees south latitude was desert (compared with about 10 percent today) and India's monsoons had virtually ceased.

Fossils found in alluvial deposits near London, England, give some idea of the climatic extremes experienced in a single locale over the last half million years. Re-

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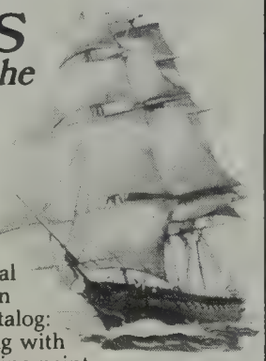

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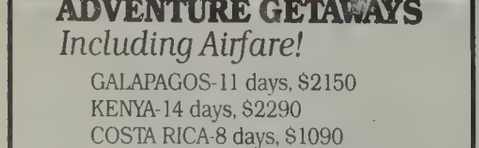

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mains of musk ox, reindeer, and woolly rhinoceros distinguish colder eras, while those of hippopotamus and hyena are evidence of climatic amelioration. There are even bones of dolphin, representing a time when sea levels were considerably higher than they are today.

Fortunately, Sutcliffe never forgets there is more to his story than grinding glaciers and ancient bones. He offers a nice explanation of geological deposition and the processes through which fossil remains are preserved. He reviews the history of paleontology and unravels the maze of overlapping archeological, geological, and paleontological divisions of Ice Age time. And in a brisk, intelligent discussion of cave art, he examines the "independent witness from a considerable number of people who had actually seen these animals."

The most intriguing parts of this book, however, are its accounts of preserved skin and hair and flesh. The frozen mammoths from Siberia are the best known of such finds, but they are not unique. The Arctic permafrost has also yielded carcasses of woolly rhinoceros, horse, bison, musk ox, reindeer, wolverine, ground squirrel, vole, and ptarmigan. With their accompanying flora (disappointingly little actually found between the animals' teeth), these remains have allowed paleontologists to reconstruct the lost world of the mammoth steppe in exquisite detail.

Even odder fragments of ancient animals have been found. The British Museum owns a piece of ground sloth hide recovered from a South American cave in 1897. Freeze-dried shortly after the beast's death, this curious artifact would appear to be more than 12,000 years old. An equally curious discovery was made in the Carpathian foothills during the early part of this century. There, remains of woolly mammoth and woolly rhinoceros were discovered in a deposit of ozocerite, a naturally occurring form of mineral wax. The accompanying assemblage of plant and insect remains unmistakably documents the tundra conditions under which these creatures existed.

A set of chapters covering different parts of the world is less successful. The one on the British Isles—the author's home range—is excessively detailed, while other areas are covered briefly and in overly broad strokes. This is particularly true for the chapter on the Western Hemisphere. I wouldn't want to make too much of Sutcliffe's assigning Thomas Jefferson eight more years in office than he actually served, but it is disappointing that this chapter devotes sixteen of its nineteen pages to the tarry soils of Rancho La Brea and Patagonia's dusty Ultima Esperanza Cave. These are important sites, to be sure, but it hardly seems parochial to suggest that the New World deserves a broader overview than this chapter presents.

The book ends with the most interesting question of all—what happened to these Ice Age beasts? What caused the mammoth and mastodon and woolly rhinoceros to pay the ultimate Darwinian penalty, while bison and musk ox survived? Why didn't the fauna of Africa suffer the kinds of losses evident in other regions of the world? And if something like climatic change caused the extinction of North America's Pleistocene horse, how have feral horses managed to reestablish themselves on the western range?

Sutcliffe examines these issues with considerable skill, posing clear questions and offering thoughtful opinions on alternative answers. His discussion emphasizes three points. First, we should not confuse "faunal turnover" with true extinction. When one species gradually evolves into something new, the ancestral type may vanish from the faunal muster, but the lineage does not disappear. This is less a real event than an artifact of our system of scientific nomenclature. Second, "each extinction must be considered on its own merits." Mammoth and mastodon were different species, filling distinctive niches and disappearing at different times. We should not be fooled into thinking they became extinct for the same reasons just because both looked something like modern elephants. Finally, with respect to the "extinction by hunting" versus "extinction through climatic change" controversy, Sutcliffe contends that most Pleistocene disappearances were probably "the result of complex chains of ecological events." Human predation may have eradicated the woolly mammoth from certain areas of the Russian plains, for example, but there is little archeological evidence of such hunting in the vast northern reaches of this creature's habitat.

On the Track of Ice Age Mammals avoids the temptation to offer easy explanations and pat answers. And because it concentrates on the data and methods of Quaternary paleontology, it will not be outdated by the next scientific convocation. Sutcliffe's thoughtful text and informative illustrations put readers in a position to understand new discoveries and interpretations as they occur. He has given us a valuable introduction to a complex and exciting field.

John R. Alden is an anthropologist and writer living in Ann Arbor, Michigan.

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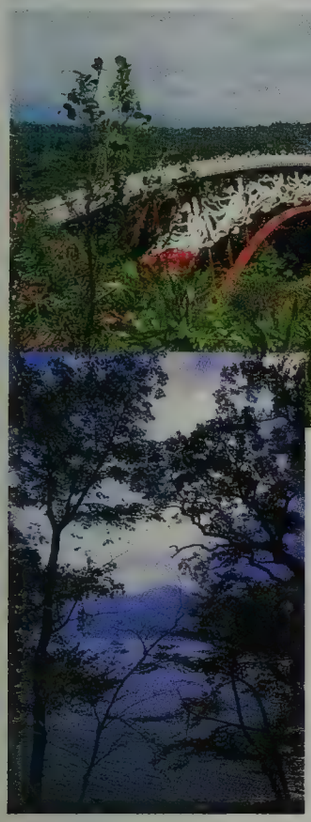

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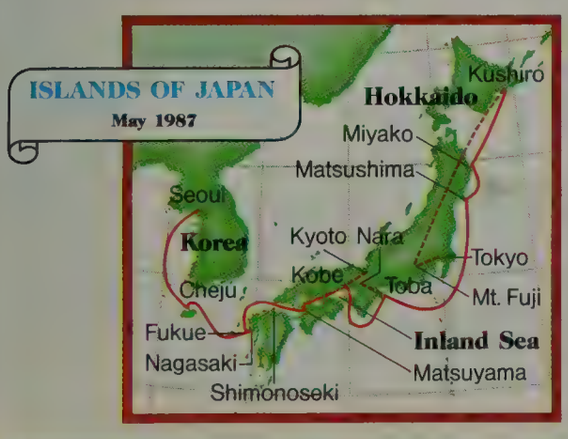

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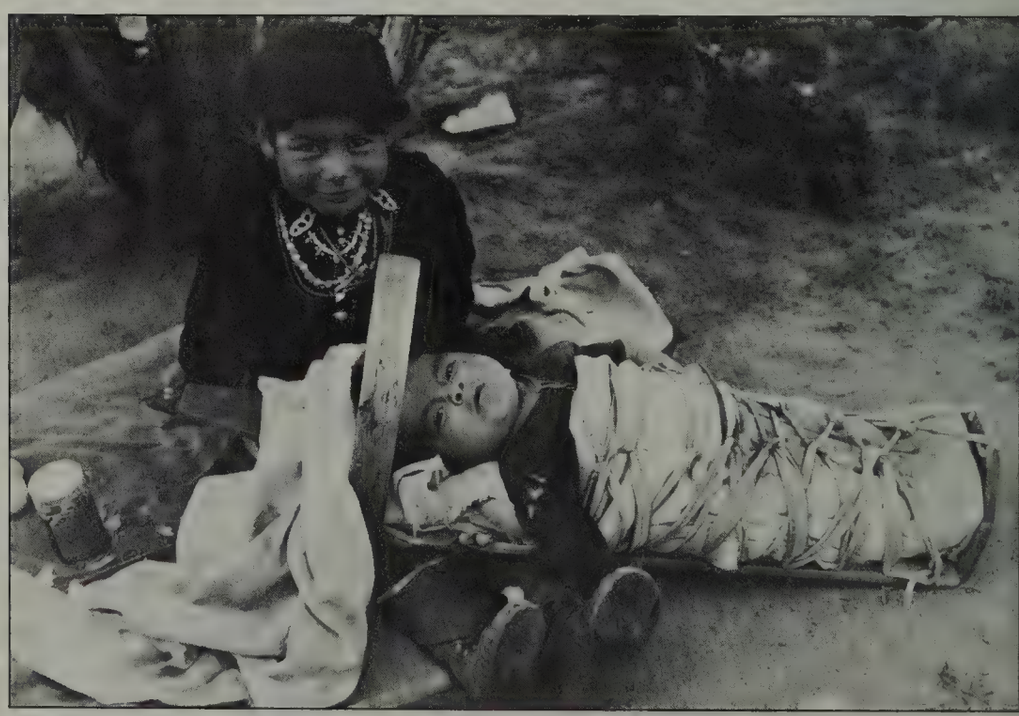
10th Margaret Mead Film Festival

The Margaret Mead Film Festival began in 1977 as a one-time celebration of the famous anthropologist's fifty years of service at the American Museum of Natural History and her seventy-fifth birthday. Ten festivals later it remains the Western Hemisphere's preeminent showcase for anthropological films.

For five consecutive evenings, beginning Sunday, September 14, the Museum's four theaters will present sixty-three films documenting cultures around the world, from Poland to Papua New Guinea. For thirty-two of them, it will be their New York premières.

"The Mead Festival celebrates the peoples of the world," says Malcolm Arth, chairman of the Museum's Education De-

Native Greenlanders rethink their move from dog sleds to jets in Inughuit: The People at the Navel of the Earth, *to be shown on September 18.*



A Weave of Time, *which follows a Navajo family through five generations, will be premièred on September 18.*

artment. "It provides glimpses of other ultures and insights about one's own soci-y. It reminds us of the rapidity with hich cultures change and of the role film an play in providing a visual record of vents that otherwise might be lost."

Anthropologists and filmmakers attend very screening, and each film is followed y a short period for questions from the audience. Each year more then 6,000 filmgoers have attended the festival.

This year's festival opens with the première of a British-made film on Mead's work; it will be followed by two short films she created with anthropologist Gregory Bateson nearly fifty years ago. Mead, who died in 1978, is still a major part of the festival that carries her name.

At the American Museum

Margaret Mead Film Festival

This year's Margaret Mead Film Festival will feature sixty-three films, thirty-two of which will be shown in New York for the first time. Films will be screened September 14 through September 18, beginning each day at 6:30 P.M. For information call (212) 873-1070.

Acupuncture and Electrical Therapy

The Museum's Education Department will host a symposium on acupuncture and treatments using electrical stimulation on October 18, from 1:00 to 4:30 P.M., in the Kaufmann Theater. Dr. Yoshiaki Omura, president of the International College of Acupuncture and Electro-Therapeutics, will lead this symposium of six scientists and therapists. For information call (212) 873-1070.

At the Hayden Planetarium

Voyage to the Outer Planets, the first show of a double bill, follows two *Voyager* space probes as they fly past Jupiter, Saturn, and Uranus. Gregory Peck narrates the second half of this double feature, *Starborn: Earth's Odyssey through Time and Space*, a dramatization of the earth's violent birth more than five billion years ago and the rise and fall of the dinosaurs. For information call (212) 873-8828.

City of Light

In 1985, a team of photographers from Harvard University traveled to India to document death and cremation in the holy city of Benares. On September 24, *City of Light*, an exhibit of their photos, will open in the Akeley Gallery. Among the pictures to be displayed are recurring images of three individuals: a healer who attends to the ill and troubled, a priest in his small shrine on the Ganges, and the Dom Raja, untouchable king of the cremation grounds. This show will be on view until March 1.

Army Ants

The social systems of army ants and slave-making ants are among the most complex in the world of invertebrates. Howard Topoff, research associate at the Museum, will discuss the evolution of ant social behavior. This program, which is free and open only to members, will take place on September 30, at 7:30 P.M. in the Main Auditorium. Tickets are required. For information call (212) 873-1327.

Social Beavers

The habits of the beaver will be the subject of a weekend program as naturalist-author Hope Ryden discusses findings from her two-year study of a beaver colony in Harriman State Park, New York. This illustrated program will take place on September 28, at 1:30 A.M. and 3:30 P.M. in the Kaufmann Theater. Tickets are $2.00 for members and $3.50 for nonmembers. For additional information call (212) 873-1327.

Man and Nature Lectures

Stephen Jay Gould, *Natural History* columnist and one of America's foremost writers and thinkers on evolutionary theory, will present the 10th Annual Mack Lipkin Man and Nature Lectures. On October 8, he will discuss "Why History Matters: An Evolutionist's View," and on October 9, his topic will be "The Contingency (and Good Fortune) of Human Evolution." The lectures will take place at 7:00 P.M. in the Main Auditorium. Tickets for the series are $15 for members and $20 for nonmembers. For information call (212) 873-1327.

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Let 4,000 Flowers Bloom

Saffron, a symbol of hand labor, is now an oddity

by Raymond Sokolov

I hesitate to repeat the essential facts about saffron because I fear that in so doing, I may encourage some food zealot to repeat the folly of F——, the wife of a minor official in Fairfield County, Connecticut. F——, having been told by another woman of fashion that, at $2,000 a pound, saffron was the world's most expensive spice, determined to pursue it as she had learned to pursue other badges and emblems of luxury. She hunted for wholesale outlets or bargain retailers—without success. So F—— went to the source, as she imagined it to be. One early spring morning, she began poking and squinting at the insides of the crocuses on her lawn, trying to pick out the stigmas.

Actually, it wasn't as addled a project as it may sound. Saffron is made from the stigmas of crocuses, but only the stigmas of one variety: *Crocus sativus*. This species—according to White Flower Farm, which was selling bulbs for a steepish $7.65 a dozen in its 1986 fall catalog—is purple with deep purple veining. Note the season: *C. sativus* is an autumn crocus, which is why F——'s feckless foray wa foredoomed from the first. But even if sh had coyly waited a few months—in th meantime locating an established plantin of the right flowers—she would have bee in for a disappointment come Septembe The large orange-red stigmas of the crocu in question might have dried into a stran or two of usable saffron, but even to pr duce an ounce of the stuff, our F—— would have had to ransack the sexual ap paratus of 4,000 flowers. Once she learne this, she gave up the game, figuring would be less trouble and more fun to g on a saffron pilgrimage to the blue crocu fields of Spain or Kashmir.

In the end, F—— stayed home, ca culating that she could get the best ba gain of all by omitting saffron from he risotto milanese or paella valenciana an substituting Mexican marigold petals c turmeric. After all, the point of saffro was to color rice yellow, wasn't it? Didn its name come into English via the Spar ish word *azafrán*, which was derived fro the Arabic word for yellow?

Crocus sativus

Peter Menzel; Wheeler Pictur

Matter of Taste

But F——, as usual, missed the point. ll you wanted out of saffron was yellow e, you could easily use cheap substi- es. Turmeric certainly does turn things low. F—— had once had the devil's n time purging its stain from a wooden tula she had used to stir a curry. The ive coloring principle is known as cur- min and comes from the rhizome of *rcuma longa*, as does the spice (the entific name comes from the Hebrew rd for saffron; confusion in these mat- s is primordial). For centuries, cur- min has been a popular dyestuff in the r East. And turmeric has been a popu- spice, produced by boiling, cleaning, ing, polishing, and then grinding the zomes of *C. longa* to a yellow powder. relative of ginger, turmeric does actu- y add more than color to food. It has a ngent flavor of its own. But in the West as long been viewed merely as a cheap bstitute for saffron. F—— could have ced her mistaken point of view back as as Marco Polo, who reported from ina in 1280: "There is also a vegetable ich has all the properties of true saf- n, as well the smell as the color, and yet s not really saffron."

That statement goes a long way toward dermining Polo's authority as a re- ter. Anyone who has seriously at- ded to the smell and taste of saffron uld not possibly have missed its strong ell. It was once even used as a perfume. d the Mediterranean cooks who are re than willing to incur the high cost of manual harvest and meticulous drying he flamboyant tripartite stigmas of this nt do so because they cannot imagine a uillabaisse or a paella without its unmis- able flavor.

Like turmeric, saffron can be used as a ; the active principle is called crocin. ffron was once admired as a medicine, d you will be pleased to know that it is h in riboflavin, although most of us will k for cheaper sources of this essential amin. In ancient and medieval times, ffron was in such wide use in so many

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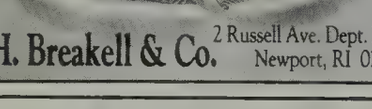

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ways that it was commercially grown even in England and gave its name to the crokers who grew it. Saffron Walden was a great center of crociculture.

Saffron was of major importance in earlier cuisines, but it was always a very costly delicacy because of the labor-intensive harvest. Aristophanes made this point first and best. Strepsiades, in *The Clouds* compares the change in his life when, a country boy, he married a rich city girl and found himself at the wedding in an atmosphere of debauched abundance and luxury: "perfume, saffron, open-mouthed kisses, expense, gluttony . . . ."

In a comparable list of today's typical luxuries, saffron would be missing. It is an oddity. We come upon it only in a few regional specialties, the ones I've already mentioned and a few others worth wider familiarity. There is, for instance, that unexpected combination typical of the Orléans region of France, pike with saffron (a local crop at Boyne), which exemplifies a whole repertoire of vanished fish and saffron dishes also recorded in England.

In Cahors, in the southwest of France, tripe is cooked with saffron, an almost unimaginably unctuous and aromatic mixture. And in the center of the country the local *pot-au-feu*, called *mourtayrol* or *mortier*, puts together beef, ham, and chicken in a saffron-tinged broth.

In England, Elizabeth David says, the universal employment of saffron, in everything from sauces to "fruit, flesh, fowl or fish, sweet cream or savory stew . . . " was a hallmark of the distant past. Since the early nineteenth century, saffron has survived in British food only in baking, in West Country buns and cake. The decline began in the eighteenth century, and by 1770 production at Saffron Walden had ceased, commemorated only in the name of the place and its municipal coat of arms blazoned with three saffron flowers.

The Mediterranean countries did somewhat better by saffron. Paella is nothing without the flavor of saffron infused in its rice. Sardinians color pasta with it. Moroccans put saffron in couscous. And according to Paula Wolfert, in *Mediterranean Cooking,* Tunisians make "a tagine with 'bananas': really cooked mashed potatoes mixed with ground meat and grated cheese, then combined with chopped hard-boiled eggs and seasoned with salt and pepper. Saffron is used to make the mixture yellow, then it's formed into a banana shape, and cooked in boiling oil."

Today, we encounter these dishes as regional specialties. But they really belong in a different category. Normally, when we talk about a regionalism, we mean to

ıy that a dish originated in isolation in the lace where we now find it surviving. A ue regional dish belongs to its region. ut the saffron dishes are isolated only ɔw. They are the last remnants of a cui-ne that flourished from one end of Eu-ɔpe and the Near East to the other. A few ishes survived, taking on local charac-eristics perhaps, but remaining as living ɔssils of another era.

This archaic, recherché quality has rec-mmended saffron cookery to the chefs of ıe *nouvelle cuisine* in France. Much of hat seems new in their repertory is really revival of lapsed ideas—sauces without ɔur are the most obvious example. Saf-on's pungent smell and vivid color also ıtisfy the modern appetite for intense avors and visual drama. So it is that the ıree-star Parisian chef Alain Senderens has returned to medieval notions of fish cookery with his lotte (monkfish) in a sauce of leek, coriander, and saffron. Georges Blanc, at Vonnas, tints his langoustines with saffron.

This chic revival will never restore saffron to its old supremacy. It is, however, cause for pleasant reflection that a substance mentioned in the "Song of Songs" and Shakespeare, a romantic rarity almost replaced by dull surrogates, a symbol of hand labor once reduced to a handful of rural recipes in remote backwaters, is gamely holding its own in an age marked by novelty, convenience, and machine agriculture.

Raymond Sokolov is a writer whose special interests are the history and preparation of food.

La Rouille

(Garlic and Saffron Mayonnaise, slightly adapted from *Roger Verge's Cuisine of the South of France*, translated by Roberta Wolfe Smoler, Morrow)

- 1 cup diced French bread
- 7 tablespoons hot fish broth
- 4 cloves garlic
- A pinch of saffron threads
- 1 egg yolk
- ½ cup olive oil
- Coarse salt
- Freshly ground white pepper or Cayenne pepper

1. Place the diced French bread in a small bowl with the fish broth. Let soak until the bread can be mashed into a paste.
2. Peel the garlic, and using a mortar and pestle, crush it into a paste. Then incorporate the saffron, egg yolk, and well-saturated bread, and work them with the pestle until thoroughly blended.
3. While turning the pestle with a circular motion, add the olive oil in a steady stream. When all the oil has been incorporated, the rouille will resemble a thick, mayonnaiselike emulsion. Add salt and pepper to taste. If the rouille should become oily and tend to separate, add 2 tablespoons hot fish broth (or water, if necessary) and continue to stir. Serve, over croutons rubbed with garlic, with fish soup.

Yield: 8 servings

Iranian Stew of Quinces and Lamb with Saffron and Split Peas

(from *Uncommon Fruits and Vegetables: A Commonsense Guide*, by Elizabeth Schneider, Harper and Row)

- 1 large onion, coarsely diced
- 1 tablespoon light vegetable oil
- 2¼ pounds lean stewing lamb in large pieces
- About 3 cups water
- About 1½ teaspoons salt
- Pepper to taste
- 3 fragrant quinces
- 2 tablespoons butter
- ⅓ cup yellow split peas, picked over and rinsed
- About ⅓ cup fresh lemon juice
- About 1 tablespoon sugar
- ¼-½ teaspoon saffron threads in 2 tablespoons boiling water

1. In a heavy flameproof casserole over moderate heat, stir onion in oil until browned. Add meat and brown on all sides. Add water, 1¼ teaspoons salt, and pepper. Simmer gently, covered, for one-half hour.
2. Meanwhile, quarter quinces and cut out every bit of the cores and seeds. (Reserve this in the refrigerator to cook with stewed fruit for added body and flavor.) Cut into ⅛- to ¼-inch slices. Sauté over moderate heat in a very wide skillet in the butter until lightly colored—about 5 to 10 minutes.
3. Add quinces, split peas, ¼ cup lemon juice, and 2 teaspoons sugar to the lamb. Bring to a boil, then turn to lowest heat. Add saffron liquid. Cook, partly covered, until the peas and lamb are tender—about one hour, stirring gently every now and then. You may have to cook a little longer or add a little water; keep testing.
4. Adjust lemon juice, sugar, salt, and pepper to taste. Cook, then cover and refrigerate until serving time.

Note: Like most stews, this one improves if allowed to mellow a day or two before serving. Skim off fat before reheating. Serve with fluffy, long-grain rice, preferably imported basmati or an aromatic grain grown in the United States—such as Konriko Wild Pecan, Texmati, Della, or Ellis Stansel Gourmet Popcorn rice.

Yield: 6 servings

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A Planet-studded Evening Show

by Thomas D. Nicholson

When the sun sets on September 23, the autumnal equinox (located in Virgo) is on our western horizon and the vernal equinox (halfway around the sky, in Pisces) is rising above the horizon in the east. All the planets of the solar system are in the sky above us at that time, all "evening stars." From the setting sun, they will stretch across the sky to the left: first Mercury in the constellation Virgo, then Venus and Pluto in Libra, Saturn in Scorpius, Uranus in Ophiuchus, Neptune and Mars in Sagittarius, and Jupiter in Aquarius. This remarkable assemblage of planets in the evening sky, all above the horizon at sunset and all gathered in one half of the sky, while there are no planets in the other half, is of no particular significance. But it doesn't occur very often and it will produce an outstanding display of planets this autumn.

Of these evening planets, Uranus, Neptune, and Pluto are telescopic objects only; and Mercury, bright enough to be easily visible in the dark, sets before we can see it. That still leaves a fair show, consisting of Venus, Saturn, Mars, and Jupiter. After evening twilight ends, they will be the four brightest objects in the sky: Venus in the west, virtually at its brightest as an evening star; Saturn nearby and above it; Mars, past its peak brightness but still an attention getter, in the south; and Jupiter, second only to Venus in brightness, rising in the east.

Trace out all four planets some night and note that the line between them dips low in the sky to the south. That's where the ecliptic (the earth's orbital plane projected onto the sky) crosses the sky on autumn evenings. The orbital planes of the planets are always found on or near the ecliptic. The part of the ecliptic traced out in the evening sky this September is called the "descending" branch because its course between the equinoxes is south of (below) the earth's equatorial plane. That's why planets in the fall evening sky are always low and may be difficult to see. Such is the case with Mercury, particularly this month, and that is why we call its fall evening elongations "unfavorable."

Events in the calendar below are given in local time unless otherwise indicated.

September 1: This morning's thin, waning crescent moon is in Cancer, with the stars of Leo barely visible until dawn. The lustrous stars above the moon are Pollux and Castor, the "twins" of Gemini.

September 4: New moon is at 2:10 A.M. EST, in Leo.

September 5: Mercury drifts past the sun today at superior conjunction (in line with, but beyond, the sun). It enters the evening sky as it emerges to the sun's left (east).

September 6–7: The young crescent moon may be visible in the western twilight on the evening of the 6th and it will surely be seen easily on the 7th above bright Venus. As darkness deepens in the west, the first object that appears above them is Saturn and the next is the reddish star Antares, both in Scorpius.

September 8: The star near the crescent

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moon tonight is Zubenelgenubi, one of two stars that identify Libra easily in its position out in front of Scorpius. The other star, Zubeneschamali, is above Zubenelgenubi but of approximately the same brightness.

September 9–10: An occultation of Antares—visible in parts of Europe, Africa, and Asia—occurs during daylight on the 10th. From the 9th to the 10th, the moon shifts from the left of Saturn and Antares to their right.

September 10: Jupiter joins the ranks of evening stars when it reaches opposition from the sun today. Along with Venus, Mars, and Saturn (and even Mercury after the 5th), Jupiter is above the horizon at sunset. It is barely an evening star as yet, but will still be visible for a while from dusk through dawn.

September 11: First-quarter moon, at 2:41 A.M., EST, is in Ophiuchus. It sets close to midnight on the evening of the 11th, after moving into Sagittarius, where we see it high in the sky after dark. It is also at perigee (nearest the earth).

September 12–13: Mars is occulted by the moon over Antarctica early on the 13th. The bright red planet is to the moon's left on the evening of the 12th, to its right on the 13th, and in Sagittarius on both nights.

September 14–16: The waning gibbous moon paces off the distance between Mars and Jupiter, in Capricornus these nights. It is nearer to Mars on the 14th and in Aquarius and nearer Jupiter on the 15th and 16th.

September 17: After conjunction with Jupiter at about 9:00 A.M., EST, today, the moon is east of the planet (to its left) by the time you see it tonight. They stay close to each other as they move west, while the moon reaches its full phase (opposite the sun) at thirty-four minutes past midnight EST. This is the moon we call the harvest moon, which appears to set almost with the rising sun for several nights in a row.

September 18–22: The waning gibbous moon rises later nightly as it moves through Pisces and into Aries, remaining in the sky longer after daybreak on each succeeding day. It moves into the easily recognized stars of Taurus before rising late on the 22d.

September 23: About midmonth the sun moved into Virgo. Today it arrives at the point in the constellation called the autumnal equinox (where the ecliptic dips south of the equatorial plane), and autumn begins in the Northern Hemisphere and spring in the Southern Hemisphere. Days and nights are supposedly of equal duration the world over today (hence the *equinox*). Investigation, however, shows that sunset occurs twelve hours after sunrise on the 26th, not today. The difference results from the way we calculate the times of these events.

September 23–24: The moon spends the last half of these nights above the horizon in Taurus. Look for the Pleiades (the Seven Sisters) close by to its right on the 23d and Aldebaran, a reddish star in the V-shaped group called the Hyades below it on both nights.

September 25: Moving out of Taurus into Gemini during the evening, the moon is at apogee (farthest from the earth) at about 5:00 P.M. and at last-quarter phase at 10:17 P.M., EST. You can find it after midnight.

September 27–28: Moonrise is at about midnight in Gemini, virtually in line with the constellation's "twin" stars, Pollux and Castor. Moon and stars move up the sky together during the morning hours of the 28th.

September 30: At month's end the late crescent moon is in the morning sky in the constellation Leo, just above Leo's bright star Regulus. They rise about 2:00 A.M. and the moon remains visible past dawn after the stars of Leo have faded.

Editor's Note: The Sky Map in the July issue shows the evening constellations and stars for this month and gives the dates and times for use.

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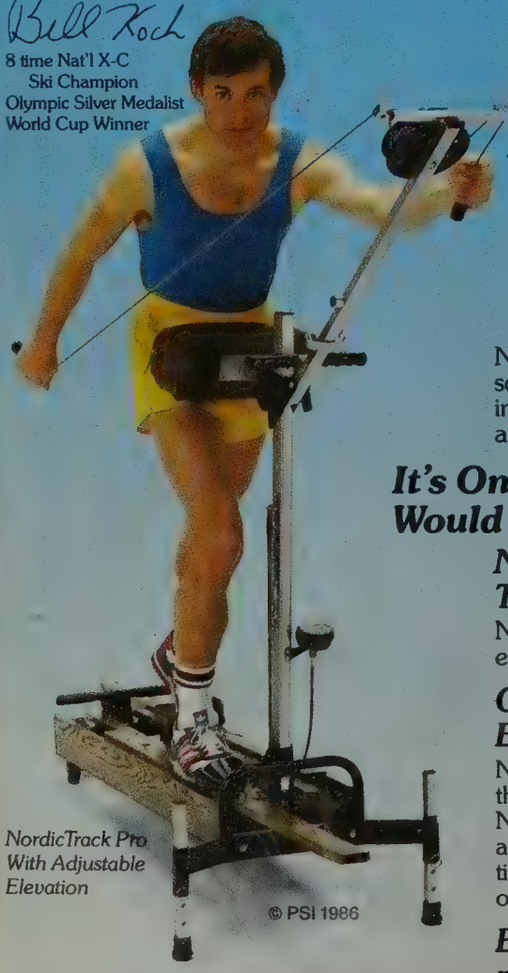

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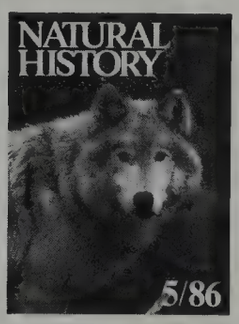

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Tail of Woe

As this butterfly fish found out, one can get taken in by the local color among the Râs Muhammad coral reefs in the Red Sea at the tip of the Sinai Peninsula. Diving on these extensive reefs, photographer Jeff Rotman came across this five-inch fish, already stung by the powerful nematocysts of the anemone and being drawn head down and digested. Nematocysts are stinging cells used by cnidarians such as hydra, jellyfish, and anemones to poison or paralyze prey. The cells are fluid-filled capsules along the anemone's tentacles. When hairs that protrude from the cells come into contact with prey, they trigger barbs in the cells, which shoot out within a few thousandths of a second. Attached to the barbs are filaments through which venom is injected into the victim. This butterfly fish, says Rotman, must have been clobbered.. Even for an anemone about the size of a head of cabbage, this fish was an unusually large catch. Rotman watched the anemone work on the fish for some forty-five minutes. With only the tail left to be digested, Rotman took this photo and moved on.—*B.D.S.*

Photograph by Jeff Rotman

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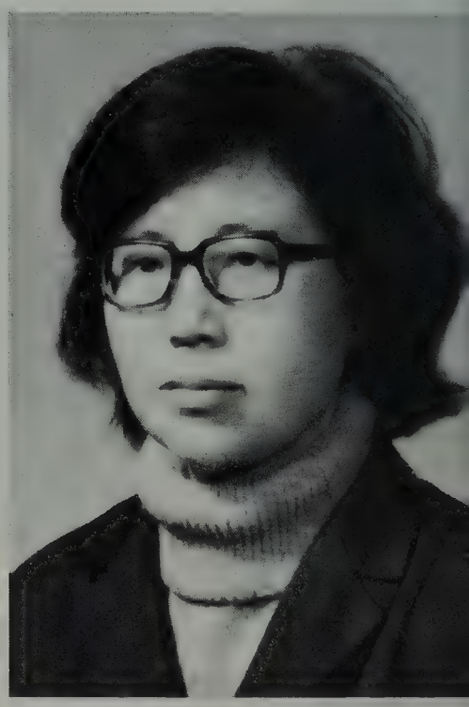
Authors

Xu BoAn (page 34) is associate professor of architecture at Qinghua University in Beijing. He graduated from the university's Department of Architecture in 1954 and has spent the years since then designing buildings and continuing his studies in the history of ancient Chinese architecture. Among the projects he worked on are the Memorial Hall of Chairman Mao in Beijing and a number of other monumental edifices. In addition, Xu, below, has published several papers on ancient Chinese architecture. Coauthor **Guo Daiheng**, right, a 1960 graduate of the same university, is now an instructor in architecture there. Guo



has also been an editor and served on the editorial board that published the monograph *A Collection of Papers on the History of Science and Technology* and the book *The History of Chinese Ancient Architectural Technology*, both published in Chinese. For readers who would like to learn more about Chinese architecture, the following books are recommended: *A Pictorial History of Chinese Architecture*, by Liang Ssu-ch'eng edited by Wilma Fairbanks (Cambridge: MIT Press, 1984), and *The Art and Architecture of China*, by Laurence Sickman and Alexander Soper (New York: Penguin Books, 1971).

Jeff Rotman (page 92) has been an underwater photographer for the last ten years. Since he has a home in Israel, he spends a great deal of time shooting along the coral beds off the tip of the Sinai Peninsula, where he took this month's "Natural Moment." Using a Nikonos with an extension tube and 28-mm lens, Rotman photographed the anemone and fish at a depth of about forty feet. His most recent book, *Undersea life* (New York: Stewart, Tabori, and Chang, 1985), features photographs taken in waters around the world.

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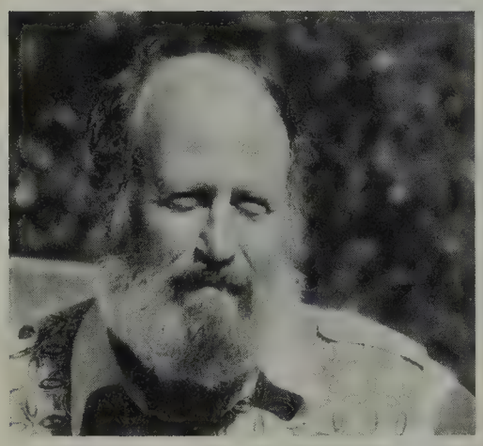
For six years, **Jerry O. Wolff** (page 44) has been studying territoriality, aggression, and life-history characteristics of white-footed mice in the mountains of Virginia. When he found out that the white-footed mouse was sharing its habitat with a subspecies of deer mouse, he became curious: were the two species competing or coexisting? Wolff's interest in small mammals ranges over various aspects of population ecology and social behavior, including dispersal, mating strategies, and mechanisms to avoid inbreeding. This month, he begins a new job as associate professor of biology at Villanova University, in Pennsylvania, after seven years as assistant professor at the University of Virginia and two as director of Virginia's Mountain Lake Biological Station. Wherever he is, Wolff finds himself drawn to the woods for both work and pleasure; he enjoys camping, birding, and wildlife photography. Occasionally, he leads field trips to Alaska. For more information about how animals fit into their environment, he recommends John R. Krebs and Nicholas B. Davies's *Behavioural Ecology: An Evolutionary Approach* (Boston: Sinauer Associates, 1984). In the March 1983 issue of *Natural History*, John Wiens discussed the role of competition in community structure ("Competition or Peaceful Coexistence?"), and in the April 1978 issue, Paul Anderson explained the success of another mouse species, the house mouse ("The Serendipitous Mouse").



Paul Y. Sondaar (page 50) became intrigued with islands, and their effect on mammal evolution, during a 1963 excursion to Crete, where he collected a foot bone of a dwarf hippo. The fossil was not only small but also different in shape from the same bone in a mainland hippo, indicating an animal well suited to walking in the mountainous island terrain. Fieldwork has taken Sondaar to Cyprus, Majorca, Sardinia, and several Indonesian islands. Among his current projects is the study of early humans in island environments. Sondaar has been a lecturer in the Department of Paleontology at the University of Utrecht, the Netherlands, since 1963. For additional reading on the subject, he recommends *The Geography of Evolution*, by George G. Simpson (Philadelphia-New York: Chilton Books, 1965). Although the book is intended for the specialist, its clear style makes it suitable for the interested layperson. "You read it like a novel," Sondaar says; "It still inspires me every time I read it."

When **Robert Alvo** (page 58) was ten years old, his family moved from Montreal, Canada, to Greece. There his boyhood relationship with birds at first involved a pellet gun. On reaching his teens, however, he exchanged the weapon for a pair of binoculars, to become, he believes, "the only birdwatcher in Thessaloniki." Returning to Canada as a seventeen-year-old, he began to work toward a bachelor of science degree at Queen's University in Kingston, Ontario, and wrote his undergraduate thesis on common loons. Later, as a graduate student in the Biology Department of Trent University in Peterborough, Alvo became the project biologist of the Ontario Lakes Loon Survey. This project had been initiated by Long Point Bird Observatory and allowed Alvo to accumulate some baseline data that could be used to assess "how well loons were doing." He used the data that he collected in the field for his master's thesis. Alvo's nonornithological passions include team sports such as soccer and softball, and his childhood on two continents left him with a love for travel. For further reading, he suggests Tom Klein's *Loon Magic* (Ashland: Paper Birch Press, 1985) and *Wilderness Birds of the North: The Common Loon*, by Judith W. McIntyre, to be published next year by the University of Minnesota Press.

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Vol. 95, No. 10, October 1986

American Museum of Natural History, New York, N.Y.
Robert G. Goelet, President
Thomas D. Nicholson, Director
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4 Letters

6 Witch Lynching at Juniville *Alfred Soman*
In the law courts of sixteenth-century France, "harmful magic" was a difficult crime to prove.

16 This View of Life *Stephen Jay Gould*
Archetype and Adaptation

31 Castaways of Caste *Jayashree B. Gokhale*
Thirty years ago this October, half a million Hindus publicly abandoned their faith.

40 Airlifting the Oaks *W. Carter Johnson and Curtis S. Adkisson*
A hardwood forest can migrate about 380 yards per year—with the help of a population of blue jays.

48 Mappers of the Deep *Marie Tharp and Henry Frankel*
The dramatic discovery some thirty years ago of a rift valley in the Mid-Atlantic Ridge helped change the accepted view of how the earth's landmasses were shaped. In this memoir, the geologist who first suspected the rift's existence tells how the discovery came about.

64 Nodes from the Underground *Randy Moore*
South Africa's low-profile window plant flouts the elements.

70 Needles and Spear-throwers *Robin Dennell*
Sewing is probably Homo sapiens' *most underrated technological advance.*

80 This Land *Robert H. Mohlenbrock*
Tajique Canyon, New Mexico

88 Reviews *Alison Jolly*
A Life Among the Chimpanzees

94 At the American Museum

96 Celestial Events *Thomas D. Nicholson*
A Good Month for Planets

102 A Matter of Taste *Raymond Sokolov*
Here We Go Round the Mulberry Bush

106 The Natural Moment *Photograph by Edward Rooks*
"One, Singular Sensation. . . ."

108 Authors

Cover: *This 13,000-year-old spear-thrower joins other artifacts in "Dark Caves, Bright Visions: Life in Ice Age Europe," opening at the American Museum October 23. Photograph by Musée des Antiquités Nationales. Story on page 70.*

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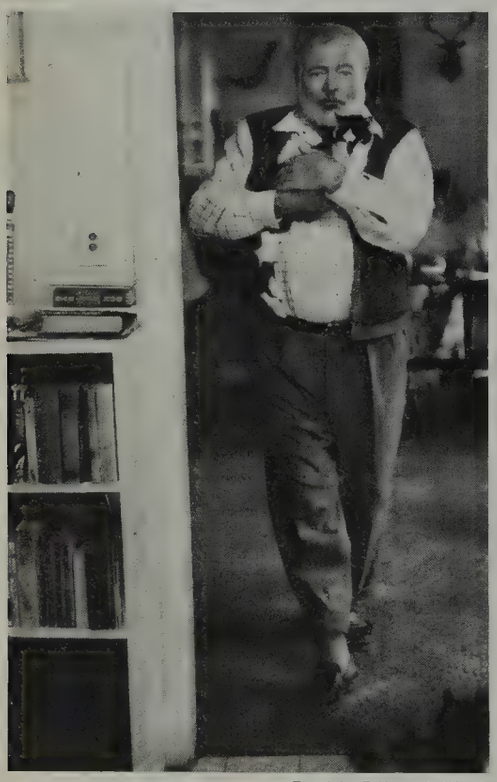
Hemingway's Feline Legacy

Andrew Lloyd's article, "Pussy Cat, Pussy Cat, Where Have You Been?" (July 1986), was most interesting. I grew up on the island of Key West, where there are many, many polydactyl (extra-toed) cats. Locals call them "Hemingway Cats," and



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the folklore has it that when Ernest Hemingway visited his Key West home in the 1940s and 1950s, he brought these cats with him. Almost forty years later, their many-toed descendants are all over the island.

SUSAN PETTY
Santa Barbara, California

Ecology of AIDS

In "The Natural History of AIDS" (May 1986), Matthew A. Gonda writes that "it is possible that the virus has existed in humans in central Africa for hundreds of thousands of years, but that it resided in an isolated population." Once these isolated infected Africans came in contact with Americans and Europeans the disease spread to their respective continents.

But Americans (through the slave trade) and Europeans (through colonization) have been in contact with most African tribes for hundreds of years, and yet AIDS was not noted in America and Europe until after 1980. If Dr. Gonda is correct, we must admit the possibility that the virus had been introduced into Europe and America previously in the last hundred years but that the disease was unable to spread sufficiently to attract the attention of the medical community. In order to make sense of the present epidemic, we must consider the behavioral changes in the recently infected population that have favored the successful transmission of AIDS.

The increase in intravenous drug abuse, sexual promiscuity, and anal intercourse in the 1970s created the ecological milieu in which this difficult-to-transmit virus could be successfully inoculated into susceptible individuals. Increased host susceptibility may not be due to lack of coadaptation, as Dr. Gonda hypothesizes, but to more frequent exposure to the virus.

RICHARD B. JOHNSON, M.D., M.P.H.
Suffolk, Virginia

Dr. Gonda Replies:

Dr. Johnson is quite correct in pointing out that the changes in personal behavior that have become more common during the past several decades have contributed significantly to the spread of AIDS, particularly outside of Africa. Moreover, it is certainly possible that the AIDS virus previously entered American and European populations in the last one hundred years but went unnoticed until AIDS appeared and began to increase in prevalence in the 1970s.

However, one cannot attribute the recent, rapid, worldwide spread solely to changes in behavior. First, demographic changes in Africa were essential for the spread of the virus. In my article I mentioned that Africa's tribal and geographical boundaries broke down as individuals moved toward cities and that such changes could have brought an infectious agent into contact with previously unexposed populations, both international and local. The devastating effects of the virus would have been felt more readily in such groups, as when visna virus (a lentivirus that infects sheep) was introduced to Iceland. These changes certainly imply more frequent exposure of the general population (and individuals) to the virus. Furthermore, the rapid spread of the virus in Africa does not appear to be related to changes in personal behavior.

Phylogeny's Tree

Stephen Jay Gould's concerns ("Linnaean Limits," August 1986) about the impact of lateral gene transfer on the geometry of evolution are shared by many other systematists. However, the problem is at once simpler and more complex than his article implies.

It is more complex because other well-known processes of evolution also threaten the pattern of divergence. Gould cites fungi and bacteria as groups without clear-cut hierarchy, and he could have mentioned the flowering plants as well. The problem in flowering plants is one of simple hybridization: new species can arise from hybrids of other species and thus represent a fusion of the twigs of phylogeny's tree. Hybridization in many fungi is quite complex, involving single organisms containing nuclei from disparate sources that unite in the sexual process in an apparently random manner. Bacteria lead even more bizarre sex lives; they can exchange single genes or large parts of their genomes through direct contact, by means of viruses, or even through their environment, and these exchanges can take place between "species" as easily as within. It becomes a semantic problem to decide whether these mechanisms constitute "lateral transfer" or "sex."

The process of divergence leaves its signature in the organisms that have diverged. This is manifested in the larger view by the Linnaean hierarchy but more specifically by groups of organisms that share unique features (homologies) that they have inherited from a common ancestor. Shared gene sequences can be evaluated by the same techniques that are used to reconstruct phylogeny from flowers, bones, or proteins.

CURTIS CLARK
California State Polytechnic University
Pomona, California

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Witch Lynching at Juniville

Although they were too late to save Guyot Girard, the central authorities moved decisively to end the abusive witch trials that arose in sixteenth-century France

by Alfred Soman

Fifteen eighty-seven was not a plague year in eastern France, but the summer was a bad one for livestock. All over the province of Champagne, horses, cattle, and sheep were mysteriously sickening and dying. One farm would be spared, the next would be hard hit. And the people began murmuring that it was witchcraft.

Their fears were intensified by fiery Sunday and feast day sermons, delivered not so much by the village priests as by the sincere but overzealous itinerant preachers (Dominicans and Jesuits) who were bringing new religious awareness to the countryside. Did not the book of the Apoc-

New York Public Library, Rare Book Room

Satan, in the form of a five-horned goat (upper right), presides over a witches' Sabbath. The illustration is from French demonologist Pierre de Lancre's 1612 Tableau de l'inconstance des mauvais anges *("Description of the Faithlessness of Evil Angels").*

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[1]Total return for the year ending 6/30/86 includes change in share price and reinvestment of all dividends and capital gains distributions. Figures update page 5 of the fund's Prospectus. Total returns for the 5 years ended 6/30/86 was 164.94%.

[2]Total return for the 10 years ended 6/30/86 was 594.99%. It includes change in share price, reinvestment of all dividends and capital gains distributions, and the fund's 2% sales charge. Figures update page 5 of the fund's Statement of Additional Information. S&P 500 is a registered trademark of Standard and Poor's Corporation (a widely-recognized unmanaged index of stock market performance).

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alypse predict that the coming of the Antichrist would be heralded by great swarms of heretics and witches? A half century after the Protestant Reformation shattered the unity of Christendom, there were heretics aplenty. King Henri III was childless; the heir to the throne was a Protestant. And if the province of Champagne had nonetheless remained predominantly Catholic, the king seemed busier making treaties with his heretic nobles than trying to exterminate them. France had been wracked by twenty-five years of intermittent civil war and lay vulnerable to attack by powerful Spain.

Many sermons blamed the plight of war-torn France on the moral failings of the French themselves. The Bible clearly instructed, "Thou shalt not suffer a witch to live" (Exod. 22:18). Yet the villagers had learned through experience th bringing a witch to trial and obtaining conviction was no easy matter. You had *prove* the charges, even though everyo knew who the witches were or, at any rat who some of them were. "Burn those start with," was the message of th preachers, "and when God sees his a flicted people upholding his comman ments, He will take pity on us and give succor. No help can be expected fro God unless the people show they have th will to help themselves. The loss of w power is a sure sign of damnation."

The cardinal of Reims disapproved such talk. He and his brother, the duc Guise, were the leaders of the militar Catholic faction trying to force Kir Henri III into an alliance against the Pro estants and also to secure the royal succe sion for the Guise family, which cou trace its descent from Charlemagne. B as the largest landowner in Champagne– his revenues were second only to those the crown—the cardinal opposed lettin his villagers take the law into their ow hands. On this issue he was the king's all

Across the border to the east was th impressively named Holy Roman Empir in reality a loose federation of principa ities with almost no political cohesio There it was easier to prosecute witche The crime was defined by law, "harmfu magic" was punishable by death, tortu could be used freely and repeatedly extort confessions, and many nobles rein bursed part of the cost of trials and execu tions incurred by the villages in purgin themselves of these servants of Satan. I the kingdom of France, however, ther was no statute governing witchcraft. was a common-law offense, like theft, a sault, murder, or arson.

An accusation of arson, for exampl was very difficult to prove. The chain evidence began with a publicly know conflict, an ultimatum or a threat ove heard by witnesses, such as, "I'll roa your fleas!" Sometimes there was test mony linking the accused to the scene the crime. But unless two impartial wi nesses actually saw the culprit with flaming torch or a bucketful of live coal or the defendant could be made to confes the prosecution had no case. In theor torture could be used to elicit a confessio when the presumption of guilt was ver strong. But the high court of appeals, th Parlement of Paris, no longer allowed th rural courts to use torture, and the way was inflicted in Paris was so mild that on one in thirty or forty persons broke dow and confessed. Those who never confesse were acquitted or banished.

If arson was so difficult to prove, witc

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A plate from E.D. Hauber's eighteenth-century Bibliotheca Acta et Scripta Magica *illustrates the widespread belief that a witch would not sink in water.*

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craft was well-nigh impossible. How could there be any witnesses to an intangible act like the casting of a supernatural spell? The law seemed designed to protect the criminal and prevent justice from being done. One solution might have been to change the law to redefine the crime, loosen the rules of evidence, and make harsh punishments mandatory. Almost every political entity in Europe made new witchcraft laws in the sixteenth century. France was a notable exception.

Even in the absence of new legislation, however, the definition of the crime tended to be subtly shifted by the prosecution, searching for a chink in the defense's armor. Witchcraft trials were originally about *maleficium*, or "evildoing"—casting spells on people, their farm animals, and their crops. While *maleficium* was virtually impossible to prove at law, it was easier to make a charge of Devil worship stick. Attendance at witches' Sabbaths might be a mass delusion, but it was subject to eyewitness testimony (as spells were not). And so a marginal aspect of European witch lore took on the star role in this gruesome drama. A suspect would be tortured until he confessed to being present at the "Devil's dance" and denounced others whom he saw there. These in turn were put to the rack to obtain further denunciations, and so on. At their worst, chain-reaction witch trials lost everything but the most tenuous connection with *maleficium*, and a Pandora's box was opened as people took advantage of the panic to settle old scores.

The cardinal was concerned when not only on his lands, where he was responsible for the administration of justice, but also in the nearby duchy of Rethelois, local magistrates began discovering "evidence" of vast numbers of witches in the region—7,760, according to the judge of the village of Brieulles. The dignity of French justice was threatened. But troops could hardly be sent in to maintain order. Such an ill-considered measure might drive the whole province into open revolt and create local support for an invasion by Spanish armies.

Instead, the cardinal appointed Rodolphe Carré as his special judicial representative to go out to the villages and indict those local judges who were trying witches without due process of law. Whenever possible, the suspects awaiting trial were to be removed from their native villages and brought to Reims or to Paris, where cooler heads would decide their fate. This tactic saved eighteen "witches" from burning in the village of Givry, but when Carré got to Juniville he was too late. Guyot Girard had already been lynched by his fellow villagers.

The surviving records tell us quite a bit about how Guyot Girard died but very little about how he lived. He might have been a typical rural witch. Most of them were women, but when men got into the act they generally did so on a larger scale and consequently made themselves more conspicuous and liable to prosecution.

In almost every village there were one or two inhabitants with a reputation for talent in matters of the occult. Often the talent was inherited, the secrets passed down from mother to daughter or from father to son. For the most part French peasants lived on relatively good terms with their witches, for they were useful people to be on good terms with. When something valuable was lost or stolen the sorcerer helped get it back. "Cunning" men and women were skilled in the use of herbal remedies and in prayers to ward off evil. As healers their record was probably just as good as that of licensed physicians in that era of misguided medical theories.

For more than three centuries now, one of the hallmarks of an educated person in France, England, or the United States is that he or she disbelieves in witchcraft and treats the whole matter as superstition and ignorance. Historians of the witch craze have become accustomed to writing about innocent victims charged with imaginary crimes, forgetting that when the neigh-

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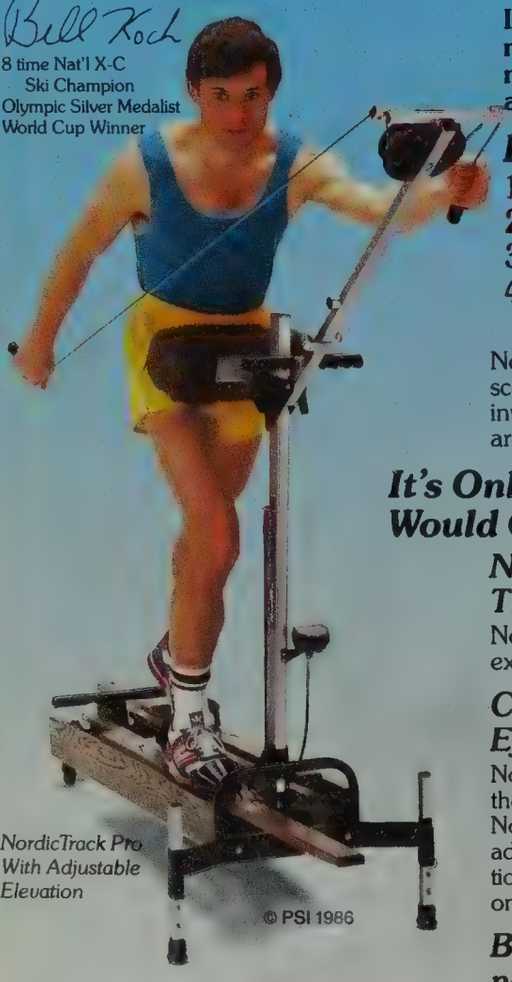

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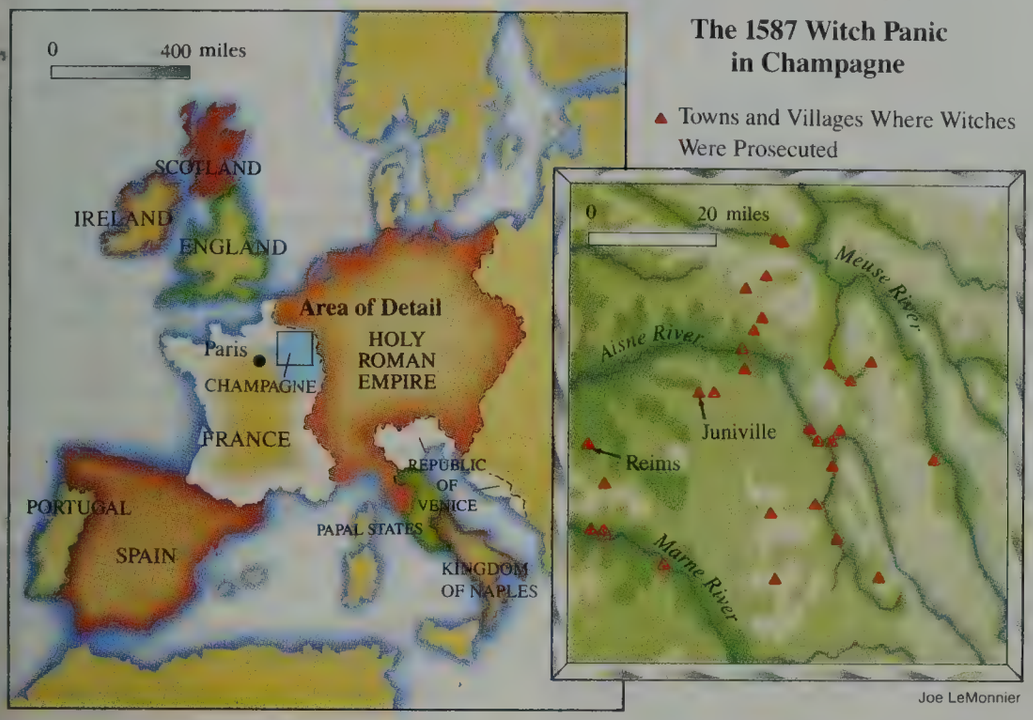
bors all believe in witchcraft and agree that a certain person possesses supernatural powers, the belief itself confers extraordinary power on the labeled individual. Such people find themselves in a position to operate a shakedown racket on the peasants who are afraid of them. Catherine Lemoine, who was lynched at Belval-en-Argonne, used to go about the village asking for alms and threatening those who refused to give. "I'll make you regret that," she would warn, and misfortune would usually strike the house where she had been turned away empty-handed.



When a witch panic struck Juniville and other villages in the province of Champagne in 1587, at least fifty people were lynched or executed illegally for witchcraft.

Not all suspected sorcerers took advantage of their diabolic reputations. The tactic was dangerous. A blacksmith in a village about thirty miles west of Juniville was caught selling witchcraft insurance at ten gold crowns a policy—one policy for the frightened customer (with whom he'd been playing cat and mouse); another for his wife and family. The blacksmith was arrested, tried, and condemned to death. At first he admitted his dealings with the Devil, then changed his mind and appealed to the Parlement of Paris. The death sentence was confirmed, he was hanged, and his body burned at the stake. It is hard to work up much sympathy for him. He was a criminal and knew the risks he was taking when he embarked on his nefarious career. Other sorcerers who never confessed to Devil worship, but against whom there was a strong presumption of *maleficium*, were banished: some for a few years; some for life. Because torture was used so moderately in France, confessions and, therefore, legal executions were relatively rare.

The case of Guyot Girard was altogether different from this legal procedure. His trial was exactly what the cardinal of Reims was trying to avoid, since it was bound to discredit the local courts, which

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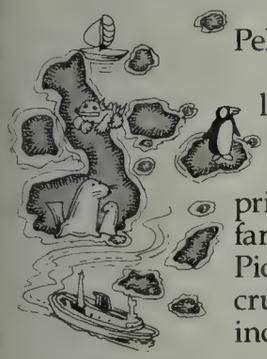

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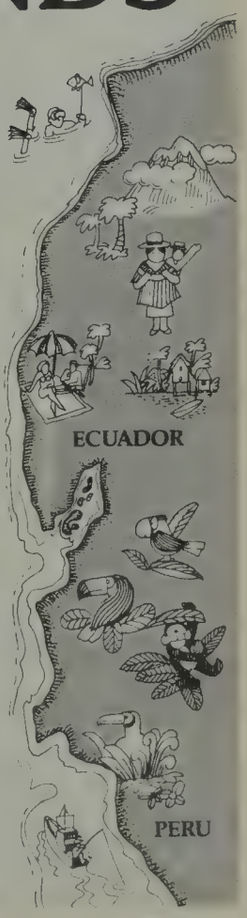

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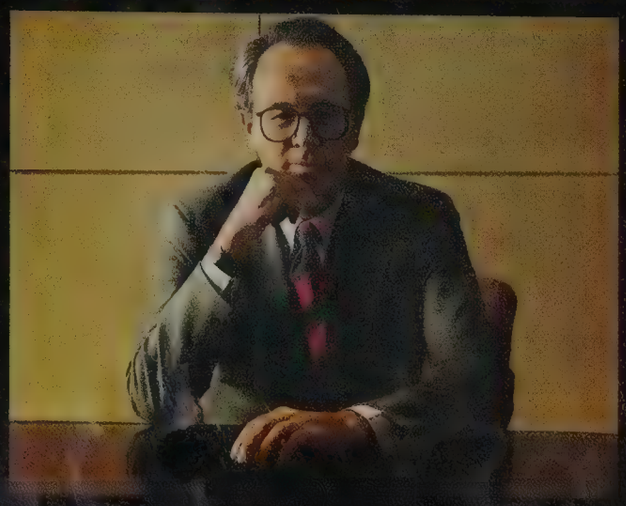

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(there being no police) were the only bulwark against lawlessness and disorder.

Girard was arrested and charged with sixteen bewitchments going back more than ten years. Particularly vehement against him was the well-to-do farmer Nicolas Leger, who claimed that Girard was responsible for a fatal spell that had killed Leger's first wife and their children. As the cardinal's representative pieced together the story, Leger was the principal rabble-rouser in the affair. After the event, Leger claimed that he did nothing except follow the orders of the mayor, Pierre Quinquet, and the other village officers. They in turn protested that they were forced to go along with Leger and his mob. Otherwise, they would have been accused of befriending witches and lynched together with Girard.

In any case, the whole village had assembled on both banks of the river Retourne while Girard was subjected to the "ordeal by water." (Today, the river is hardly more than a wide stream: the water table has fallen in the region and many rivers where witches were "swum" are scarcely deep enough now to get one's feet wet. Four hundred years ago the Retourne was probably a good deal deeper.)

The water test consisted of tying the suspect's wrists and ankles together and throwing him into a river, a pond, or the moat of the local castle. A rope was attached to him, so if he sank he could be pulled up before he drowned. Only an innocent person would sink, water being the symbol of purity and of Christian baptism. A witch, having sold himself to the Devil and renounced his baptism, would be rejected by the water.

Villagers all over Europe believed in the water ordeal. Many offered voluntarily to undergo it—to prove their innocence to their neighbors (perhaps also to themselves). But it was frowned upon by the high magistrates in Paris and by their allies like the cardinal. It was a vestige of the old judicial ordeals—trials by battle, trials by walking through fire—that existed before modern investigative methods made them obsolete. "Swimming a witch" smacked of superstition, of contending with the Devil on his own terms (with the risk of being the Devil's fool). Worst of all, it was an unseemly public spectacle and the crowds too often got out of control.

To the solemn sound of a drum roll, Guyot Girard was trussed and tossed into the river. Nicolas Leger held the rope, and Mayor Quinquet warned that he would fine anyone who interfered. But when Girard floated, Leger stripped down to his shirt and drawers and dove into the water. Three times he tried to push the witch

down. Three times he bobbed back up to the surface.

"The witch won't drown!" shouted the crowd. "Let's see if he'll burn!" The lynch mob now had all the proof it wanted of Guyot Girard's guilt. What followed was a cruel mockery of justice.

Legal execution was by hanging, the cadaver afterward being burned at the stake. Forty or fifty years had elapsed since the French authorities had burned people alive, although they sometimes went through the traditional motions. An occasional sentence would still prescribe that the victim feel the heat of the flames before he was hanged; in practice he was mercifully garroted before the fire was lit. There was to be no *coup de grâce* for Girard, however. He was heaped about with straw and twigs and set ablaze. The fire symbolized the victory of the village over the Devil, who was powerless to save his witch. Only then was Girard—still alive?—hanged on the gibbet.

When Carré later interrogated Leger about his starring role in the lynching from its beginning to its end, the farmer came up with a stock excuse: after the water ordeal, the prisoner tried to escape and just coincidentally ran straight at Leger. He, Leger, was innocent of any premeditation; his prominence in the lynch mob was purely fortuitous. Whether or not this was true, once the excitement was over and Rodolphe Carré began asking embarrassing questions, the village needed a scapegoat and Nicolas Leger was an obvious choice.

There was a second scapegoat as well: Regnault Roussel, the collector of fines. For there had been another nasty incident in Juniville at about the same time. The documents are rather hazy on the details, but it seems that a man executed as a witch in a neighboring village had denounced the Juniville widow Gillette Prevost. Roussel did not wait for formal charges to be pressed. He had her hanged by the feet until she confessed. Although she retracted her confession, she was condemned to death, whereupon she appealed to the Parlement of Paris.

No special reason was needed to appeal a criminal sentence. All that was necessary was to declare, "I appeal"; the local court was then obliged to send the prisoner to Paris, at enormous expense. If Gillette had been convicted legally, it would have cost the village the equivalent of sixty to eighty cows to have her sentence confirmed and bring her back to Juniville for execution. No other country in Europe had such an extravagant, and effective, system of controlling its criminal courts.

The Parlement of Paris was known to be extremely severe when the rights of appellants were infringed. The mayor of Juniville felt that his hands were tied. Not so Roussel. Under the pretext that the widow had renounced her right to appeal, he had her executed. The populace played no part in her death, so the result was not exactly a lynching; but her trial was, to say the least, abusive.

Leger and Roussel were tried in Reims at the cardinal's own court, which had jurisdiction over all his vast landholdings in Champagne. They were both found guilty of homicide and sentenced to be hanged. The mayor of Juniville, the town prosecutor, the schoolmaster (who doubled as court clerk), the sergeant at arms, and two other participants in these miscarriages of justice were all condemned to be present at the execution, each with a rope around his neck, and banished for five years from the region.

Only Leger and Roussel appealed. The six others perhaps felt they had gotten off lightly. Appeal was a double-edged sword. A lower court's sentence was usually mitigated, but it could also be stiffened. Actually, it made no difference whether the

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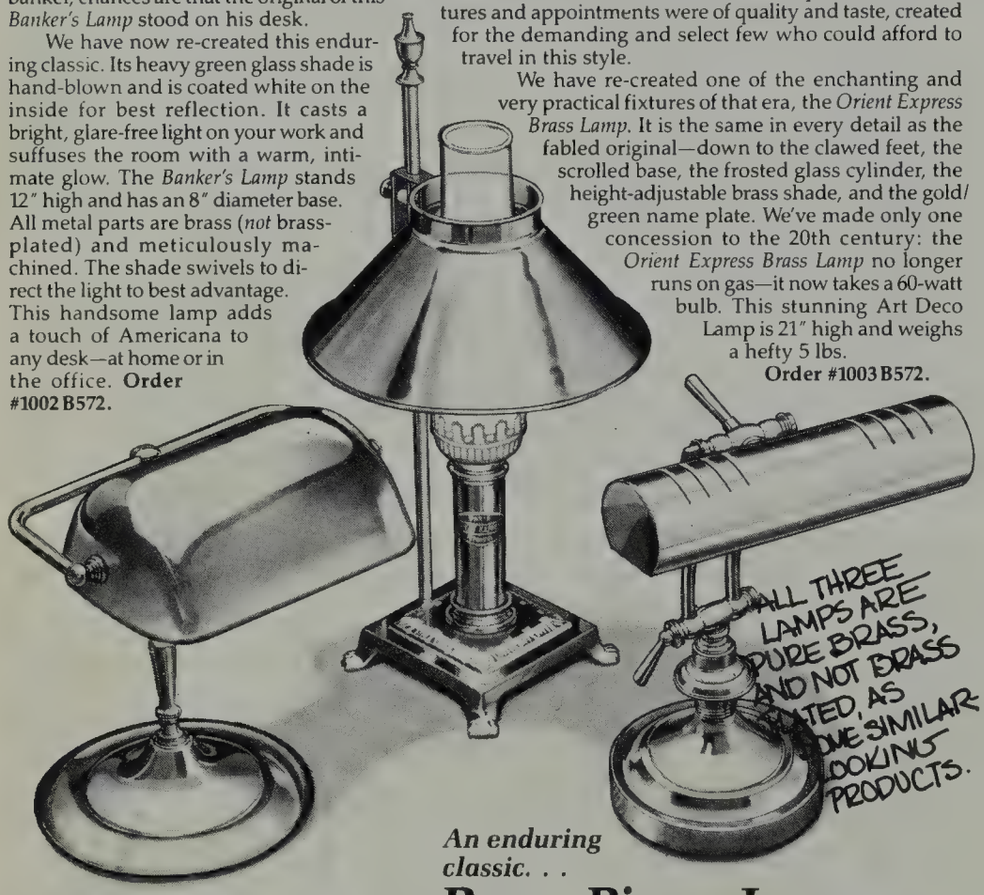

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others appealed or not, as the high court was not going to review the cases of two of the defendants without hearing the other six. Leger and Roussel benefited from the parlement's customary clemency. Instead of being hanged, they were condemned to do public penance in Reims "for having, on their own private authority, swum several persons suspected of witchcraft and brutally maltreated them," then to be flogged through the streets and banished from the province for nine years.

The mayor and the town prosecutor had their sentences increased. They too had to perform public penance "for having looked on and tolerated the said swimming and cruelties," then to be exiled, also for nine years. The remaining four got off with a lesser degree of public humiliation: to be present at the ceremony, bareheaded and on their knees, to hear their fellows confess their misdeeds.

There were at least six other lynchings that year and more than fifty persons illegally executed for witchcraft, within a radius of twenty-five miles of Juniville. The witch panic in Champagne was a major concern to the high court, as it quickly established a fourfold program to put an end to the disgrace: (1) punish the responsible magistrates (taking care not to provoke a backlash); (2) acquit the victims of abusive trials, regardless of the evidence against them; (3) outlaw the ordeal by swimming; and (4) make appeal obligatory in all trials for witchcraft. The fourth measure was extremely radical. There was no precedent for it and it took years before it was enacted, partly because the political situation was deteriorating rapidly.

In May 1588, the Guise faction drove the king out of Paris. At Christmastime, Henri III retaliated by having the duc and the cardinal killed. The following August the king himself was assassinated, and France was plunged into another ten years of civil war.

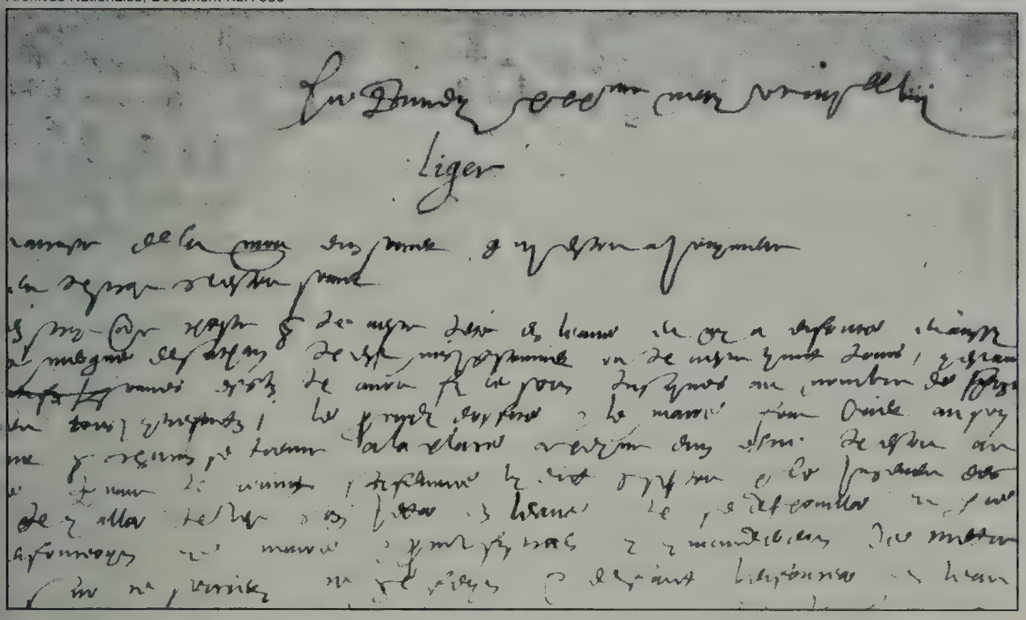
With the return of peace, the province of Champagne remained relatively tranquil—until 1623, when another panic broke out. This time the political background was favorable and the parlement acted decisively. Appeals were at last made automatic for all witchcraft convictions, and the acquittal rate for the next seven years was higher than two out of three; the number of trials dropped off sharply. For all practical purposes witchcraft had been decriminalized. The last witch to be executed legally in the jurisdiction of Paris (half the kingdom) was Catherine Bouillon, in 1625.

Witchcraft trials came to an early end in France, not because people stopped believing in witches, but because the central

authorities considered the trials scandalous and unbefitting the dignity of the king's justice. The proponents of witch hunting had been the lower-to-middle ranks of both clergy and magistracy. Where the central authorities were weak, the zealots had their way, and thousands of innocent people were tortured until they confessed and were burned at the stake. This is what happened in Scotland and in many parts of the Holy Roman Empire, not only German principalities, but also some French-speaking provinces not yet incorporated into the kingdom of France. The trials continued until the late seventeenth century in western Europe and spread to America, to Scandinavia, and in the eighteenth century, to eastern Europe. But where the central governments were strong enough to resist the pressure—in England, France, and Spain—there were comparatively few witch trials and they were largely a thing of the past by 1625, long before it became intellectually fashionable to be contemptuous of belief in witches.

Meanwhile, belief in witchcraft, while less widespread than four centuries ago, is still alive today. The witches themselves are (and probably always were) shadowy figures in the background. The phenomenon can only be perceived through the activities of clairvoyants and "disenchanters" who claim to intercept a spell and render it harmless or, even better, turn it back against the witch who cast it. In August 1985, I attended a colloquium in western France where several of these white witches, or "healers," attempted to convince a group of skeptical social scientists of the reality of the evil forces they combat. Why, they wanted to know, is it impossible to bring an evildoer to justice? The answer lies in the story of Guyot Girard and hundreds of others like him. The courts learned the hard way that to prevent abuse, a crime that is impossible to prove at law must be treated as if it were no crime at all. □

Archives Nationales, Document X2A 956



A document from May 30, 1588, records the testimony of Nicolas Leger regarding his role in the lynching of Guyot Girard for witchcraft. On appeal, the Parlement of Paris reduced Leger's penalty, calling the affair an unpremeditated homicide.

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Archetype and Adaptation

The truly great intellectual dichotomies are not battles to the death, but struggles to find partial truths

by Stephen Jay Gould

Goethe features a great confrontation on high in part 2, act 4, when a cloud deposits Faust on the summit of a high mountain range, and Mephistopheles, wearing his seven league boots, arrives just a moment later. In keeping with the local scenery, they begin a fierce argument about rocks—a clash that mirrors, quite consciously (since Goethe was also a geologist), a major debate of early nineteenth-century science.

The Devil, befitting his abode, supports the catastrophic theory of major upheavals fueled by great eruptions that fracture the earth's crust and raise mountains from former ocean depths:

> Hell was with sulphur-fumes
> so much inflated
> And such a gas therefrom was generated,
> That very soon the earth's flat crust
> —no wonder!—
> Thick as it was, was forced to burst asunder.
> So now we have a different situation;
> What's now a peak was once
> a deep foundation.

Faust responds with the stately view that gentle forces of erosion, mostly running water, have slowly altered a topography stable in basic features since the earth's early days:

> When Nature in herself her own self
> founded,
> The globe of earth she formed
> and neatly rounded, . . .
> The hills in easy slopes she downward
> moulded,
> Till gently into valleys they unfolded.
> There all is verdant growth and for her
> gladness
> She has no need of such convulsive
> madness.

Diogenes Laertius, in his *Lives and Opinions of Eminent Philosophers* (ca. A.D. 200), presents the first expression of a prominent cliché: "Protagoras asserted that there were two sides to every question, exactly opposite to each other." Faust and the Devil were playing the umpteenth version of that favorite among all intellectual games: dichotomy, or "take a complex issue, discard its subtleties, then allocate all possible opinions into two categories treated as polar opposites." Coin tossing becomes our primary metaphor for resolution; as Captain Corcoran might have said, they hardly ever land on their edges.

Dichotomy also has an ethical dimension since right so easily turns to good, wrong to bad. Faust and the Devil played dichotomy with a debate about forces of geological change: neptunism (deposition of all rocks as sediments from an original ocean) versus plutonism (formation of rocks from interior magmas, with convulsive wrenching of the earth's crust during periods of extrusion). The Devil, loyal to his abode, presented plutonism; both Faust and his author were neptunists. Goethe's version made no bones about identifying goodies and baddies—although, ironically, we now read the history of geology as a victory of plutonism and might thus stand accused of satanism.

I despair of persuading people to stop playing dichotomy; the need seems to lie too deep in the human soul. Perhaps, instead, we might harness this drive to circumvent its own worst influence—our tendency to simplify and caricature complex issues. If we cannot avoid dichotomy, at least we might explore a range of different taxonomies by two. If we tried a large set of twofold divisions, placing the wall of separation at different angles and in different places each time, we might finally occupy enough perspectives to appreciate the true complexity of most issues.

As a child, for example, I could never figure out why cancer seemed so resistant to treatment, when we had developed cures for so many other diseases. If cholera, typhus, typhoid, tuberculosis, and plague had retreated as major scourges, why not cancer as well? Only much later did I realize that I had been wallowing in a false taxonomy, a bad division. If cancer were one like all others in a set of coequals, then my puzzle had merit. But if we also—and more properly—view cancer as one side of a dichotomy balancing all the others by itself, then sequential success on one side of the wall need not extend to triumph on the other side. (In this dichotomy, we contrast a class of DNA damage inducing unconstrained proliferation [cancer] with a class of foreign agents invading the body [bacterial diseases, for example]. I realize of course that such a dichotomy is also false, since various "invaders" can induce cancers as well, and since diseases come in so many more than these two classes, but this is my point. No dichotomy can be "correct," so we must explore the consequences of several.)

In my own field of evolutionary biology, Darwin's revolution defined the primary dichotomy as evolution versus creation (particularly for human origins). I have no objection to this division per se; scarcely anything else could be more fundamental. But we can parse the world in other ways, some more useful in certain circumstances. In particular, since biology before Darwin did not always view evolution versus creation as its primary dichotomy, the attempt to read this later division back into history often leads to serious misunderstanding.

This essay explores another major dichotomy in evolutionary thinking—an issue older, and in many ways deeper, than the usual version of evolution versus creation. The wall of structural versus functional approaches to form does not occupy the same position as evolution versus creation. It divides biologists along a different line and therefore qualifies as an alternate dichotomy promising different insights.

In his masterful book *Form and Function* (1916), the committed functionalist (but eminently fair arbitrator of other positions) E.S. Russell defined this dichotomy:

> The main battleground of these two opposing tendencies is the problem of the relation of function to form. Is function the mechanical result of form, or is form merely the manifestation of function or activity? What is the essence of life—organization or activity?

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nomena, but cannot infer an unambiguous sequence of past events from the simple observation of good design today. The natural world is full of structures fit for their functions, but which came first? Giraffes feed on leaves at the tops of acacia trees. But did their necks elongate in response to a need for such feeding (the functional view) or did giraffes grow long necks for reasons unrelated to utility and then discover that they could reach the succulent leaves at the tops of trees (the structural alternative)?

This dichotomy runs deeper than biology, for it expresses attitudes that have defined controversies in fields ranging from architecture to aesthetics. Shall the forms of buildings express their uses ("form follows function" of Louis Sullivan and a lineage extending to Mies van der Rohe and the international style at its best); or shall abstract principles of aesthetic design and proportion regulate architecture, with good function arising as a consequence of proper aesthetics?

In biology, the dichotomy of structural versus functional approaches to form reaches its acme at the issue of adaptation. Functionalists view adaptation as the cause of good design; structuralists view it as a fortunate side consequence. Adaptation is the primary motivation of evolutionary change on one side of the wall, but it is merely incidental and superimposed on the other.

We now reach the crux of this essay: the chief illustration of how false (and exclusive) dichotomy distorts our view of history. English and American biologists have long favored functionalist accounts of evolution—so much so that we often equate functional thinking with all intelligible ideas about evolution itself. All our primary theories—both Darwinism and Lamarckism, for example—have been functionalist in identifying adaptation as the motif of evolutionary change (by natural selection for Darwin or by inheritance of acquired characters for Lamarck). Since we make the deeply restrictive mistake of interpreting all historical debates as episodes in the great evolution/creation dichotomy, we have, again and again, badly misinterpreted structuralist theories as creationist. The false logic goes something like this: structural theories assert the primacy of form over function; since evolution is a process of adaptation, function guiding form, theories that view good design as a secondary consequence of form must be creationist, that is, they must assert the creation of form by fiat if they will not permit its gradual molding in the service of function.

This false logic set the core of last month's essay, for Fred Hoyle misinterpreted the structuralist Richard Owen as a creationist, and then advanced this misunderstanding as the basis of his accusation that Owen bought a fraudulent *Archaeopteryx* in order to discredit Darwin. But Richard Owen deserves more than vindication from Hoyle's nonsense; his structuralist ideas merit our attention because he was a great and neglected thinker, and because our own strong adaptationist biases have precluded proper attention to the important insights of structuralist thought. The two dichotomies—evolution/creation and structural/functional—are orthogonal, not coincident.

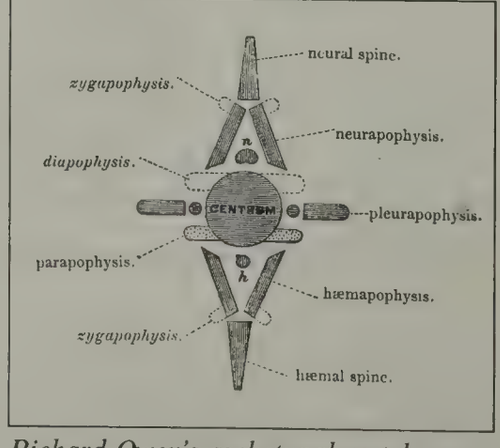
Owen presented a fascinating account of his structuralist views, in a famous address, *On the Nature of Limbs*, delivered to the Royal Institution of Great Britain and published in 1849. He begins by acknowledging that structuralist thinking, so common on the continent, receives little sympathy or understanding in England:

> I became fully conscious how foreign to our English philosophy were those ideas or trains of thought concerned in the discovery of [these] anatomical truths . . . . A German anatomist, addressing an audience of his countrymen, would feel none of the difficulty which I experienced.

Owen's argument in *On the Nature of Limbs* centers upon the identification of a beginning for vertebrates—a basic form to serve as foundation for all later alterations. This basis—or archetype in Owen's terminology—must contain within itself the potential for all variety generated later. Combine the inherent possibilities of the archetype with rules of structural transformation and you generate the taxonomic diversity of living creatures.

Don't misunderstand. We are not yet in Darwin's world. The vertebrate archetype is an idealized abstraction—a Platonic form that embodies both the kernel of unity and the constrained potential for change along definite paths—not the flesh and blood of a true ancestor. Owen, a paleontologist by trade, would never have sought the archetype on bedding planes of the Burgess Shale. Still, he felt sufficiently confident to draw the archetype as an animal and to specify and name its features.

All illustrations from *On the Nature of Limbs* (1849)



Richard Owen's archetypal vertebra

As an evolutionist, he also argued that the actual history of vertebrates would follow a set of pathways leading from true beginnings in forms close to archetypal organization (primitive fishes), toward progressive specialization of parts in "higher" creatures (birds and mammals). Owen professed ignorance about the causes of evolutionary change, but he specifically identified them as natural, and held that God is not demoted by viewing evolution as the outcome of His laws. Thus, the famous closing paragraph of his address reads:

> To what natural laws or secondary causes the orderly succession and progression of such organic phenomena may have been committed we as yet are ignorant. But if, without derogation of the Divine power, we may conceive the existence of such ministers, and personify them by the term "Nature," we learn from the past history of our globe that she has advanced with slow and stately steps, guided by the archetypal light, amidst the wreck of worlds, from the first embodiment of the Vertebrate idea under its old Ichthyic vestment, until it became arrayed in the glorious garb of the Human form.

If adaptation provides a key and driving force for functionalist theories, the idea of constraint forms the backbone for structuralist thought about evolution. Change cannot follow all possible paths dictated by external forces; an organism is not putty before a molding environment. Constraints are imposed both by starting points (the form of the archetype for Owen, perhaps the structure of DNA for modern adherents) and by rules of transformation specified by the nature of organic materials. To provide a flavor for this unfamiliar style of thought, consider an example from Owen in each category.

1. Limitation by archetypal starting point: the hallux, or first digit of the foot (big toe in humans), has one phalanx (toe bone) fewer than subsequent digits in the archetypal pattern. All higher vertebrates maintain this arrangement, even when demands of adaptation might favor a reorganization. In humans, where big toes are greatly enlarged to bear weight and littlest toes almost vestigial, big toes still contain but two phalanges, while fifth toes house three tiny toe bones. In elephants, with first and fifth toes of equal length enclosed in a massive pad, the first still bears two

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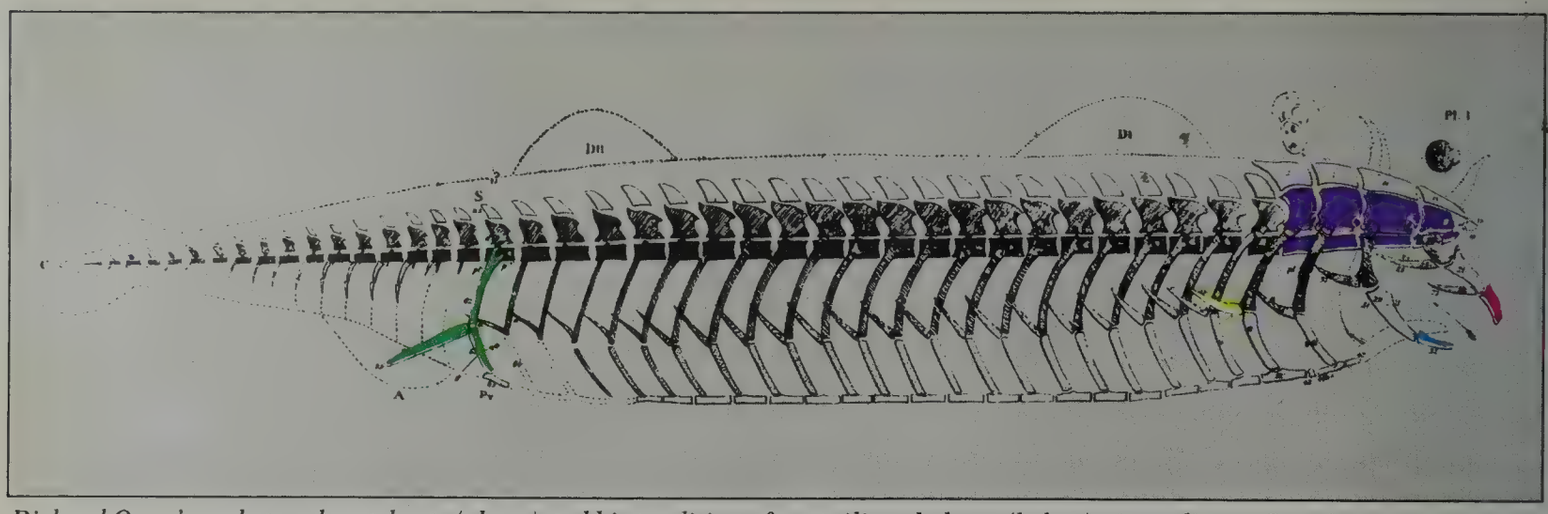
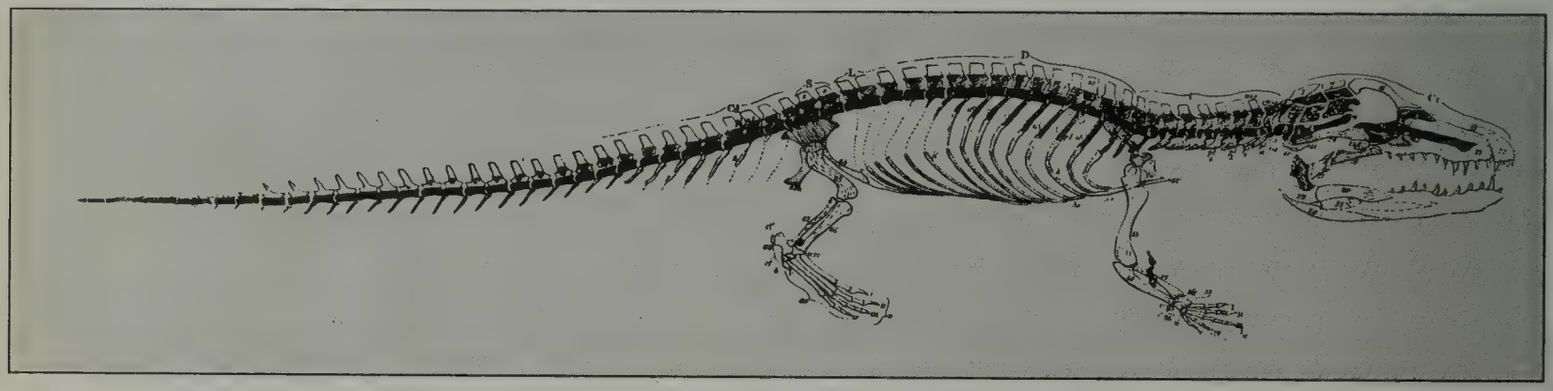


Richard Owen's archetypal vertebrate (above) and his rendition of a reptilian skeleton (below): According to Owen's schema, the skull of higher animals is an elaboration of the first four archetypal vertebrae (purple); the premaxilla of the upper jaw and the dentary of the lower jaw are the tips of the first and second haemal arches (red, blue); the front leg (or arm) is a diverging ray of the fourth vertebra (yellow); and the pelvis and hind limb are the haemal arch and the diverging ray of a posterior vertebra (green).



phalanges, the fifth three. Within the webbed hind-paddle of seals, the archetypal arrangement persists, though the first and fifth toes again are equal in length and are fully conjoined within the flipper.

2. Constraint by rules of transformation. Adaptation remains a powerful force for change, but it must work within pathways specified by laws of form. One such law dictates that primitive forms depart least from the archetype in retaining numerous, simple repeating segments, while advanced creatures yield more extensively to adaptive molding and specialization of parts. (Clearly this claim could become circular if we define primitive by retention of archetypal pattern alone. But we can break the circle by invoking independent criteria, especially the prediction that creatures closer to archetypal form should occur early in the fossil record—a claim strongly supported by Owen as the basis for his interpretation of *Archaeopteryx* as both the most primitive and the oldest bird.) "The Archetype," Owen writes, "is progressively departed from as the organization is more and more modified in adaptation to higher and more varied powers and actions."

Owen followed a tradition of both French and German "romantic" or "transcendental" biology (their names for structuralist thinking) in identifying the vertebra as a basis for archetypal form in vertebrate animals (see my column of November 1985 on the French version of this theory, as advanced by Geoffroy Saint-Hilaire). The primal vertebra, in such a scheme, is a complicated object with numerous parts above and below the spinal cord, and numerous appendages all fit for modification. The archetype becomes little more than a long set of serially repeated vertebrae surrounding a central spinal cord—as Owen's reconstruction clearly shows. All subsequent evolution in vertebrates can only modify these numerous vertebral segments in varied ways. No matter how different a skull may become from a foot in "higher" vertebrates, all are modified parts of vertebrae:

> I believe, however, that I have satisfactorily demonstrated that a vertebra is a natural group of bones . . . and that the parts of that group are definable and recognizable under all their teleological modifications, their essential relations and characters appearing through every adaptive mask.

(Note how sharply, if unconsciously, this last phrase contrasts functional with structural thinking. To functionalists, adaptation is the driving force of evolutionary change; to structuralists, it is a mask of epiphenomenal fiddling, obscuring an underlying unity of form.)

Even the form of that most advanced and complicated vertebrate, *Homo sapiens*, can be read as a maximal modification of the archetypal string of vertebrae:

> General anatomical science reveals the unity which pervades the diversity, and demonstrates the whole skeleton of man to be the harmonized sum of a series of essentially similar segments, although each segment differs from the other, and all vary from their archetype.

If the vertebrate archetype is a string of equipotential vertebrae, then we must face some interesting possibilities. Vertebrates on this earth developed parts of just two vertebrae into limbs, but if other worlds sport creatures built upon the same archetype, they might grow more pairs in different places. Owen interpreted limbs as great elaborations of small vertebral appendages called diverging rays. He then identified diverging rays on nonlimbed vertebrae of several fishes and reptiles, concluding that "they must be 'rudimental limbs,' future possible or potential arms, legs, wings or feet." He then speculated in his concluding paragraphs:

> The conceivable modifications of the vertebrate archetype are very far from being

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exhausted by any of the forms that now inhabit the earth, or that are known to have existed here at any period . . . . The discovery of the vertebrate archetype could not fail to suggest to the Anatomist many possible modifications of it beyond those that we know to have been realized in this little orb of ours.

The idea is not so preposterous as it seems at first, at least by analogy with other body plans. Insects, for example, are built of repeated segments, strongly modified. Each original segment bore a pair of simple legs. Insect mouth parts are modified legs—look carefully at films of insects feeding, for the resemblance remains unmistakable. Antennae, gill supports, swimming devices, and clasping organs all have the same source as modified legs. But Owen was wrong about skulls and limbs as altered parts of vertebrae, and his grand scheme began to unravel.

This must be the oldest trap of intellectual life: you develop a general scheme too beautiful to be false, apply it to every nuance of nature's complexity, and it dies in the details. Owen's vertebral archetype went this way of all flesh (or rather by all flesh, as the reality of muscle and bone conquered abstraction). Owen tried to interpret the skull as a complexly modified amalgam of four original vertebrae (compare his archetype with his reptilian skeleton). Note how the haemal (lower) arches of vertebrae 1 and 2 become the upper and lower jaws of actual vertebrates, while the tiny tips of the arches become the major premaxillary and dentary bones of reptilian upper and lower jaws.

If this transformation of nubbin to massive jawbone strikes you as improbable, the search for an archetypal source of limbs (the main subject of Owen's 1849 treatise) strained the theory even more. Owen did not, as Geoffroy and other continental biologists had urged, identify limbs with ribs. Instead, he equated the girdles (shoulder bones up front and pelvis behind) with haemal arches of vertebrae. (Jaws therefore become the homologs of shoulders and pelvises since all are derived from haemal arches.)

But whence, then, the arms and legs themselves? Owen identified tiny projections from the haemal arch as "diverging rays" and then argued that all the complexity of an arm—humerus, radius, ulna, carpals, metacarpals, and phalanges of the several digits—differentiated from this single, tiny, projecting spine.

But Owen's difficulties did not end with this improbable reconstruction. He wanted to identify the arms and shoulder girdle as elaborations of the haemal arch of the fourth vertebra—that is, literally as parts of the skull (since the first four vertebrae form the skull). Owen wrote: "However strange or paradoxical the proposition may sound, the scapular arch and its appendages, down to the last phalanx of the little finger, are truly and essentially bones of the skull."

In some fishes, the shoulder girdle is fastened to the rear of the skull, but numerous neck vertebrae separate skull from arms in all reptiles, birds, and mammals. This fact forced Owen to the improbable claim that the haemal arch of the fourth vertebra had migrated back past an array of subsequent vertebrae to form the shoulder and arms, while the top part of the fourth vertebra stayed put to form the rear of the skull. At this point, the archetype had been tortured beyond utility.

Owen and Darwin began as friends. As I explained last month, Darwin sought out Owen to describe his precious vertebrate fossils, brought back from South America on the *Beagle*, and Owen is the taxonomic author of *Toxodon* and its allies. But the two men became bitter enemies after Darwin published the *Origin of Species*. Most biologists, using the inappropriate dichotomy of evolution versus creation, have assumed that Owen precipitated this break because he hated evolution. But Owen was also an evolutionist. Owen despised Darwin's functionalist version of evolution, not the idea of transmutation itself. The best dichotomy for understanding their conflict is structuralism versus functionalism.

For Owen, nature presented a fundamental antithesis between laws of structure (embodied in the archetype) and the functional tinkering that overlays these basic forms with adaptations. Structure is primary; adaptation a covering veil, necessary for survival in the tough old world out there but fundamentally a nuisance for anyone trying to decipher laws of form. Darwin, in one of his most brilliant strokes of insight, took this fundamental antithesis and rendered it with beautiful simplicity as two different aspects of adaptation, temporally separated. The key passage, one of my half dozen all-time favorites in Darwin's writing, is the summary statement of chapter 6 (last edition) of the *Origin of Species*, entitled "Difficulties of the Theory." In this passage, Darwin acknowledges Owen's central contrast. He designates Owen's structural theme as "unity of type"—why should creatures employ the same structures for such different purposes, or why should I now be typing with the same finger bones used by a bat to fly, a horse to run, and a seal to paddle? Owen attributed this unity to common impress of the archetype, and viewed such resemblances as antithetical to the principle of adaptation. Darwin designates current adaptation as "conditions of existence"—the immediate fitting of form to current function and environment. Darwin writes, combining the two themes that Owen kept rigidly separate:

It is generally acknowledged that all organic beings have been formed on two great laws—Unity of Type, and the Conditions of Existence . . . . On my theory, unity of type is explained by unity of descent. The expression of conditions of existence . . . is fully embraced by the principle of natural selection. For natural selection acts by either now adapting the varying parts of each being to its organic and inorganic conditions of life; or by having adapted them during past periods of time . . . . Hence, in fact, the law of the Conditions of Existence is the higher law; as it includes, through the inheritance of former variations and adaptations, that of Unity of Type.

Darwin's dismantling of Owen's structuralism proceeds in two stages. First, he takes all the deep platonic mysteries of archetypal similarity and renders them—in such a pedestrian, matter of fact way—as simple results of descent. Similarity in finger bones does not betoken the abstract ground plan of all vertebrate existence, the basic model used by God himself to underpin all later evolution. Such similarity only indicates that all these diverse vertebrates are descendants of a common ancestor that possessed finger bones in this arrangement. Unity of type represents passive descent from a flesh and blood ancestor, not a record of primal unity.

Second, Darwin takes the major claim of Owen's structuralism—that creatures do such different things with the same design—and, by a deft argument, provides an easy explanation that invokes the rival principle of functionalism. The common finger bones did arise by adaptation—but long ago. When vertebrates first evolved five digits with the requisite number of finger and toe bones, all these structures were adaptations to conditions of life faced by that ancient ancestor.

Thus, we do not find archetypal similarity fighting current adaptation. The apparent antithesis really represents the same process—adaptation—working at two different times. We designate current operation, producing good fit of structure to function, as conditions of existence; and we identify past operation, yielding common structures later modified for a variety of uses, as unity of type.

Yet it would also be wrong, very wrong, to close the case here and view modern evolutionary theory as the triumph of

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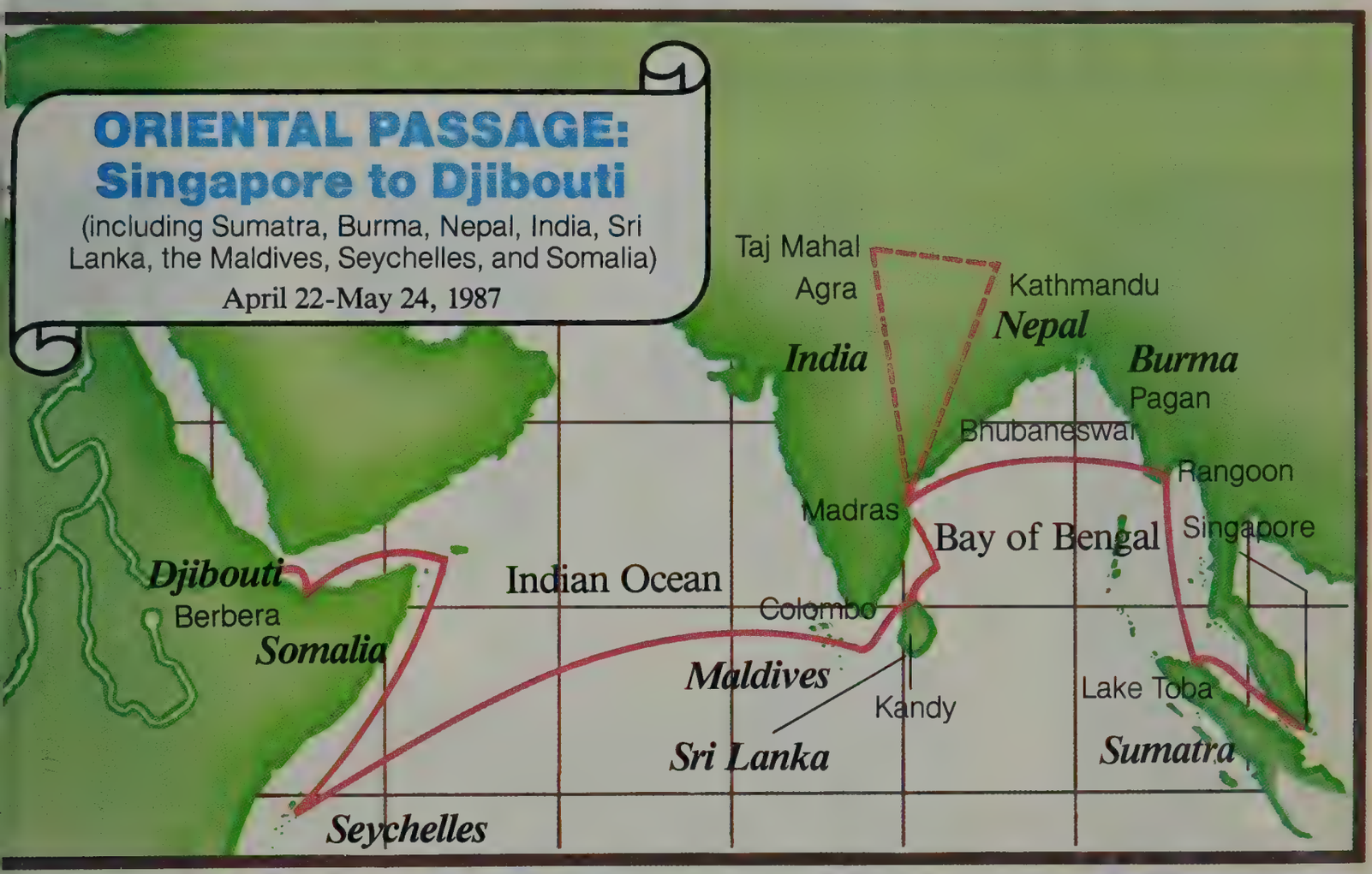

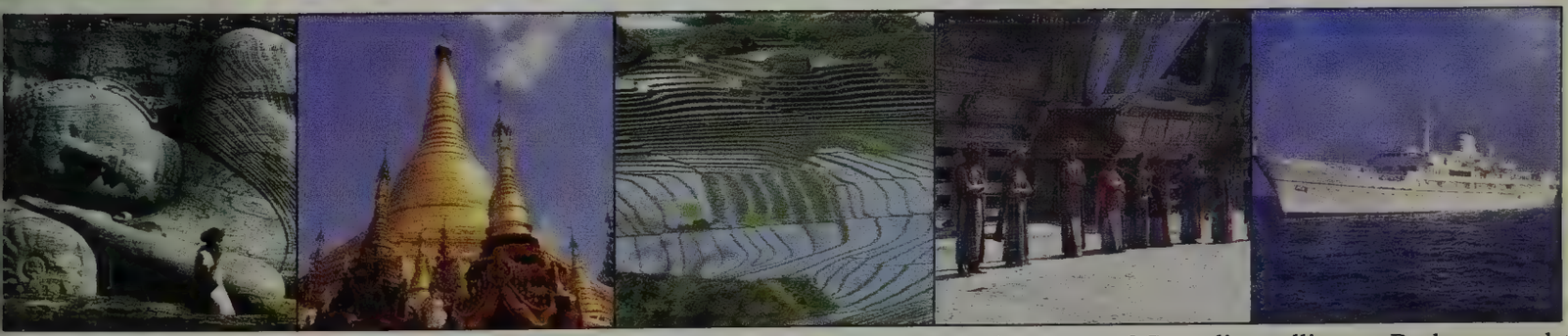

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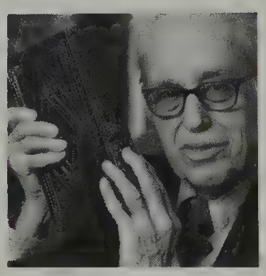

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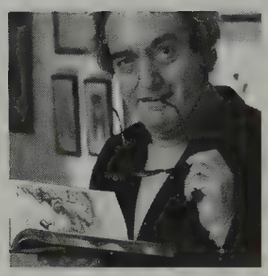

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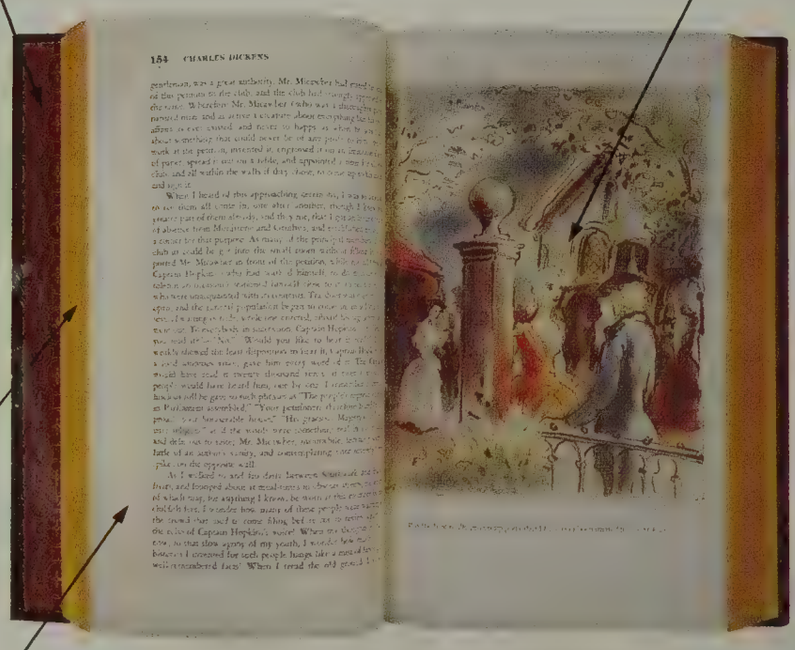

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functionalism over Owen. It is true that cardboard, caricatured Darwinism—a version unfortunately preached by many professionals, especially "for simplification" when writing for the public, but also in their technical work—espouses a silly pan-selectionism that views all structures as adaptations, and places organisms in Dr. Pangloss's best of all possible worlds. This caricature of proper science proceeds by guesswork and cleverness, not test and evidence: locate a puzzle–why in our culture, for example, do men score better than women on certain tests of spatial perception? Then make up a story—in the old days of cave life, men hunted and needed the spatial acuity, while women stayed by the hearth with the kids. (This sounds absurd, I know, but it was a popular notion just a few years ago. Our current stories are no better as science, merely more congenial with later social preferences.) Everything that exists must be "for" something, and must be explicitly designed for current function. The cleverer the story, the more successful the attempt (and the more copious the resultant publicity).

Some (too many) of Darwin's epigones espoused this crude functionalism, but Darwin did not. Darwin dethroned the archetype, but not the idea that laws of structure constrain, limit, and even direct pathways of evolutionary change. Darwin took a keen interest in principles of structure, devoting his longest work (*Variation of Animals and Plants Under Domestication*, two volumes, 1868) to constraints of inherited form rather than pathways of natural selection.

When I want to convince my dubious colleagues about Darwin's pluralism, his struggle to unite functional and structural themes, I usually quote an example from the *Origin of Species*. Here Darwin describes a feature absolutely essential to the survival of mammals but not built by natural selection, and therefore ascribed by Darwin to structural principles—unfused skull bones that "shape" the fetal head and permit it to pass through the narrow birth canal.

> The sutures in the skulls of young mammals have been advanced as a beautiful adaptation for aiding parturition, and no doubt they facilitate, or may be indispensable for this act; but as sutures occur in the skulls of young birds and reptiles, which have only to escape from a broken egg, we may infer that this structure has arisen from the laws of growth, and has been taken advantage of in the parturition of the higher animals.

Three years ago, when I was fighting cancer and unsure of the outcome, I made a double splurge after a series of lectures in Cambridge, England. I bought a first edition of Owen's *On the Nature of Limbs*, and read it on the Concorde. There, at 57,000 feet and Mach 2, halfway across the Atlantic, I made a personal discovery. That lovely Darwinian passage, so often used in my private defenses of structuralism, came directly from Owen, who wrote:

> Such a final purpose [adaptation] is indeed readily perceived and admitted in regard to the multiplied points of ossification of the skull of the human foetus, and their relation to safe parturition. But when we find that the same ossific centers are established, and in similar order, in the skull of the embryo kangaroo, which is born when an inch in length, and in that of the callow bird that breaks the brittle egg, we feel the truth of Bacon's comparison of "final causes" to the Vestal Virgins, and perceive that they would be barren and unproductive of the fruits we are laboring to attain, and would yield us no clue to the comprehension of that law of conformity of which we are in quest.

So much for dichotomies of good guy functionalists and bad guy structuralists.

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An adequate theory of evolution must meld both approaches—not into a formless compromise at the center, but by recognizing the strengths of each vision, and their appropriate places in the intellectual tug of war that any good theory for complex nature embodies. We need an evolutionary theory that unites a molding outside (natural selection producing adaptation to local environments) with a guiding inside (the structural laws that Owen sought, with an antiquated apparatus to be sure, but with a prescient vision).

Besides, the general idea behind the archetype is not wrong. At some level, unity of structure must underpin the diversity of life: such order cannot proceed from formlessness. Owen failed by seeking order at too high a level—in the explicit bits and pieces of an archetypal morphology. We would seek it today in the universal structure of genetic material, in the blueprint of DNA. That blueprint constrains evolutionary possibilities as surely as Owen's archetype channeled vertebrate form. Another architecture of inheritance would have built a very different world—perhaps of a Lamarckian nature, with evolution galloping by inheritance of acquired characters at 100 times the speed of Darwin's actual domain.

Darwin did not deny Owen's principle of limiting, universal structure. But he did have the audacity to locate this core much more distantly in time and form. Owen's God made the basic shapes of things, and then let evolution take over to produce the world's diversity. Darwin broke through and drove evolution much further back, through all explicit anatomy to unity of structure at the level of chemical building blocks.

At the end of his life, Goethe attended the greatest pre-Darwinian battle between structural and functional biology—the debate between Geoffroy and Cuvier, which was held in Paris amidst the revolution of 1830. Goethe rooted for the structuralist Geoffroy—for Goethe, early in his botanical career, had proposed the leaf as an archetype for all plant form, just as Geoffroy advanced the vertebra for animals. But Goethe also sensed the power of Cuvier's functionalism. The truly great intellectual dichotomies are not battles to the death, but struggles to find the partial truths of each vision. As Goethe concluded: "The more vitally these two functions of the mind are related, like inhaling and exhaling, the better will be the outlook for the sciences and their friends."

Stephen Jay Gould teaches biology, geology, and the history of science at Harvard University.

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2337 Wishing you all the peace and love of this Holy Season (with "For unto us a Child is born, unto us a Son is given...", Isaiah 9:6-7)—*artist Jim Fetherolf*

2460 To those we love and see each day and other loved ones far away, to all good friends whose friendship means so much ...Merry Christmas and Happy New Year!—*artist Roy Kerswill*

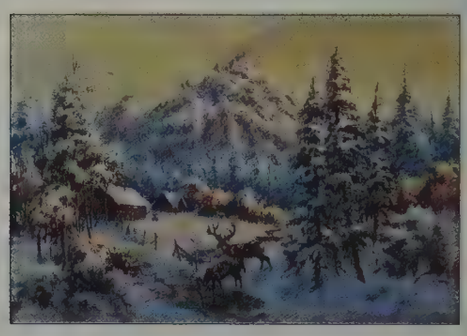
4223 Wishing you a Blessed Christmas and Happiness throughout the New Year—*photo by H. Peter Wingle*

3119 Merry Christmas and a Happy New Year (with "Nothing is so strong as gentleness, nothing so gentle as real strength." Indian Proverb)—*artist Richard Amundsen*

3332 It wouldn't seem like Christmas if we couldn't get in touch and wish the Season's Happiness to those we like so much Merry Christmas—*artist Keith Fay*

3139 Merry Christmas and a Happy New Year (with "Two things...can neither change nor end...", 4-line inspirational poem)—*artist J. Crumrine*

3227 May there come to you at this holiday time...Health, Happiness, and Enduring Friendships **NATURE'S BOUNTY**—*artist Ted Blaylock*



3211 May Peace be your Gift...and your Treasure...(with "In the heart of the wilderness...", 8-line poem)—*artist Lee K. Parkinson*

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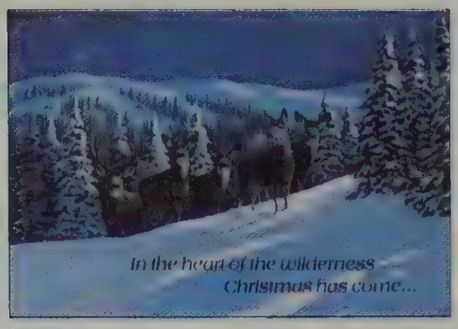
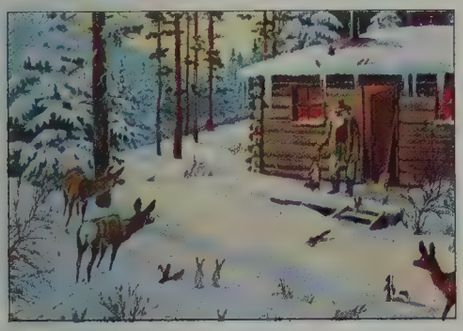
3253 Merry Christmas and a Happy New Year (with "Take Time To See", 24-line nature poem) —*artist Ted Blaylock*



3092 Merry Christmas and a Happy New Year (with "In the heart of the wilderness Christmas has come...", 8-line inspirational poem)—*artist Leslie Peters*



1142 Never too cold for kindness, never too deep the snow, to wish you the Merriest Christmas our good Lord can bestow! **A CHRISTMAS MORNING HANDOUT**—*artist Bernard P. Thomas*

2225 **Peace on Earth** May Peace be your Gift at Christmas and your Treasure through all the Year—*artist Pawnee Indian Brummett EchoHawk*

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3309 Wishing you a Blessed Christmas and Happiness throughout the New Year (with "They walk with God upon the hills!" 3-line inspirational poem)—*artist Dorrine Robertson*

3058 May Peace be your Gift at Christmas and your Treasure through all the Year (with "Take Time To See", 24-line nature poem)—*artist Garé Barks*

3261 May Christmas bring to you the music of laughter...the warmth of friendship, and the spirit of love—*artist Richard Barth*

3225 Merry Christmas and a Happy New Year (with an excerpt from "To A Waterfowl" by William Cullen Bryant)—*artist Ted Blaylock*

1485 May Peace be your Gift at Christmas and your Treasure through all the Year (with "Nature is the living, visible garment of God." by Goethe)—*photo by Abi Garaman*

3025 Merry Christmas and Happy New Year **SLEIGHBELLS IN THE SKY**—*artist Bernard P. Thomas*

3330 Merry Christmas and a Happy New Year (with "In the heart of the wilderness Christmas has come...", 8-line poem)—*artist Ted Blaylock*

3342 May you have the Spirit of Christmas which is Peace... (with "There is a quiet in the winter wood...", 4-line poem)—*artist Hayden Lambson*

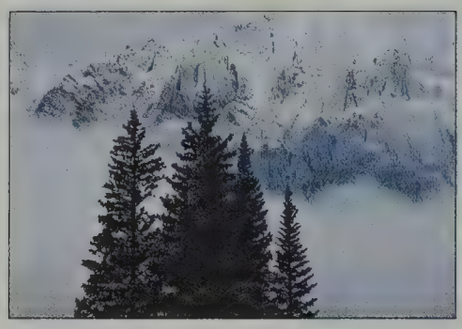
3360 May the peace and love of Christmas be yours! (with "Silent night! Holy night! All is calm, all is bright")—*artist Ted Blaylock*

3350 Merry Christmas and Happy New Year **SONG OF WINTER**—*artist Ted Blaylock*

3008 May the Peace and Joy of Christmas be with you through all the Year **THE MIRACLE OF CHRISTMAS**—*artist Garé Barks*

3152 ...for the many blessings we all share, for opportunities and adventures...and for the sheer delights of life and love. Merry Christmas and Happy New Year—*artist Richard Amundsen*

2154 May Peace be your Gift at Christmas and your Treasure through all the Year (with "May the warm winds of heaven blow softly on your house...", Cherokee Indian Blessing)—*artist Fred Fellows*

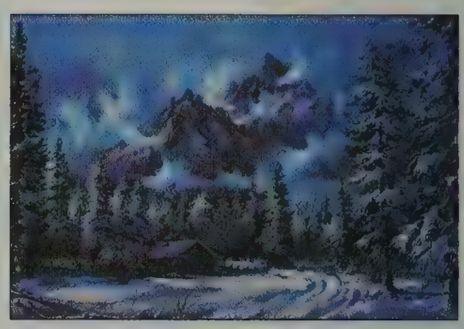


7017 Merry Christmas and a Happy New Year —*photo by David Sumner*

3234 To those we love and see each day and other loved ones far away, to all...whose friendship means so much...Merry Christmas and Happy New Year—*artist Richard Amundsen*

3337 Let us keep Christmas holding it close to our hearts for...its spirit...of remembering friends. (with "Times change, and we with time, but not in the ways of friendship")—*artist Paul Krapf*

3208 Wishing you a Christmas Season filled with Love and Happiness (with "To have joy one must share it, happiness was born a twin.")—*artist Mimi Grant*



1456 Merry Christmas and a Happy New Year (with "When pine trees bend with heavy snow and trails are hard to find...", 8-line poem)—*artist Lee K. Parkinson*

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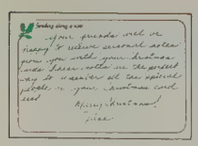

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Castaways of Caste

Rather than remain untouchables, some Hindus chose to abandon their faith

by Jayashree B. Gokhale

On October 14, 1956, hundreds of thousands of Maharashtrian untouchables, led by Dr. B.R. Ambedkar, came to Nagpur, India, to renounce their ancestral Hindu faith and convert en masse to Buddhism, breaking completely with the traditions that held them on the lowest rungs of Indian caste and class order.

For weeks before, Ambedkar's followers had publicized the event throughout the villages of the western Indian state of Maharashtra, exhorting entire communities to come to Nagpur and embrace Buddhism. Mahars streamed into the city, clogging major transportation routes. The crowds were dressed in white and were in a festive and joyful mood. The conversion ceremony began at nine in the morning with Chandramani Mahasthavir, the most aged and venerable *bhikku* (monk) in India, administering the Buddhist oaths (*tisarana*) to Ambedkar.

One of the chief architects of the Indian Constitution of 1950, Babasaheb Ambedkar was revered among Mahars as the first untouchable to graduate from high school, the first to receive a B.A. from an Indian university, the first to earn graduate degrees (from Columbia and London universities), and the first to be a barrister-at-law. He had long protested his predicament as an untouchable. "It is an unfortunate fact that I have been born a Hindu," he stated at a conference of untouchables in 1935. "It was not in my hands to oppose or change that. But I can say this with the utmost sincerity and gravity: I will not die a Hindu." Conversion, Ambedkar concluded, would be the only way for those so long oppressed to escape the taint of untouchability.

He was the first to receive his new vows, repeating each three times: "I take refuge in Buddha; I take refuge in *Dhamma* [Buddhism]; I take refuge in the *sangha* [monkhood]." The crowd at the ceremony, counted at well over half a million, waved the ocher flags of Buddhism and shouted "jaya Buddha" (victory to the Buddha, or long live the Buddha) and "jaya Bhim" (victory to Ambedkar). Ambedkar then administered the oaths to the crowd, vows that included the total renunciation of Hinduism, the complete acceptance of the Buddhist creed, the rejection of the notion that the Buddha was an avatar of Vishnu, and the resolution to abjure Hindu ritual practices surrounding death. Afterward Ambedkar declared that he felt as if he had walked away from hell. Bhimsen Dethe, a contemporary Buddhist novelist, describes the event this way:

> In the villages of Maharashtra, Maharwadas had woken up with a start. They had all flung away their village duties, and had stripped away the darkness of thousands of years. The tyranny of tradition had ended; the power of the village headmen no longer held sway. Shoulders that had carried away dead cattle and hands that were callused from chopping wood could now rest. The touch of the new revolution had destroyed the old weight of slavery! The poor souls who for centuries had been oppressed by injustice and cruelty had now become free. The chains of caste had been smashed . . . the crowd was overwhelmed, carried away in a sea of joy with the conversion to this religion.

The possibility of leaving Hinduism has always been attractive to the lower castes in Hindu society. Conversions to Islam and to Christianity brought tangible benefits. Sometimes undertaken at the behest of local leaders, these conversions were most often matters of individual choice that did not involve the community as a

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A picture of Dr. B.R. Ambedkar is carried by Hindu converts to Buddhism in a demonstration against caste violence. Formerly untouchables, they now refer to themselves as dalits, *"poor and downtrodden."*

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whole. Under Ambedkar's influence, some 55 percent of Maharashtra's untouchables converted. In 1951, there were barely 2,500 Buddhists in all of Maharashtra. By 1961, five years after the conversion, the Buddhist population was some 2.7 million. The majority of those who converted were, like Ambedkar, Mahars—the most numerous of the untouchable communities of Maharashtra, the third most populous state in India. (The Indian government, which under the country's 1950 constitution guarantees equal rights to all, refers to the untouchable communities as Scheduled Castes.) By 1971, the 3.2 million Maharashtrian Buddhists outnumbered any of that state's other Scheduled Castes.

Untouchables, as traditionally despised, impoverished, and scattered minorities, occupy the lowest reaches of India's dominant Hindu caste hierarchy. According to Hinduism's theory of varna, or caste, untouchables are permanently defiled and defiling; their role in Hindu society demands perpetual subordination. They play an essential part in the division of labor, performing all the tasks considered polluting by Hinduism—removal of animal carcasses, attending funeral pyres, leatherworking, and garbage disposal. Their position traditionally required that they live in sequestered neighborhoods beyond the village gates; their contact with caste-Hindus was limited lest their presence pollute. In India today, many of these historical and occupational patterns persist, so that, for instance, most garbagemen and scavengers are of the Scheduled Castes, and Scheduled Caste neighborhoods are at the edges of the village.

The Mahars were traditionally village servants. They considered themselves to be the original sons of the soil, who were conquered and enslaved by the Aryans. Very early in their history the Mahars were given a grain allowance from the villagers and tax-exempt lands in return for performing their hereditary tasks. These tasks were not connected to any specific occupation or trade but rather involved menial assistance in village administration. They were required by village and state authorities to contribute free labor on demand, for either public or private services. It was their job to remove the dead animals from the village streets and, after taking the hides and eating the meats, dispose of the carcasses. In addition, they were watchmen, couriers, and—in a function supporting their claim to be the original settlers of Maharashtra—adjudicators of boundary disputes. Their lack of any proprietary occupation or independent economic base meant that they were totally dependent upon the village and state for their sustenance. The state, in turn, upheld the caste hierarchy and ideology.

Central to varna are the notions of pollution, purity, and karma. Untouchables, repositories of pollution, must perform their tasks without demurral. They must endure their degraded and subservient position in the present social system in the hope that obedience and sublime faith will overcome their untouchable status in the next life. By adopting Buddhism, which rejects the distinctions and divisions of caste, the converts were attempting to combat the consciousness of caste. What followed was a dramatic rejection by the Mahars of their traditional practices and social customs. They banished images of Hindu deities from their households in favor of portraits of the Buddha and Ambedkar. Although continuing to perform some administrative and clerical services for the government (and thereby retaining their tax-exempt land), they ceased performing their tasks as village servants. The converts stopped eating carrion and no longer disposed of a village's dead animals, leaving the task to the Mangs, another of the Scheduled Caste communities. In response, the villagers stopped making contributions of grain to the new Buddhists. The absence of this allowance, coupled with the loss of income from the sale of the hides of dead animals, reduced their income in the village. Many young Buddhists left the village in search of livelihoods, mostly as casual laborers.

The conversion also encouraged migration for the purpose of education. Rural Mahar-Buddhists became determined to educate their children despite the costs and sacrifices. A survey by the Mahar-Buddhist People's Educational Society showed that 80 percent of Scheduled Caste students in Aurangabad were the first in their families to attend college and that almost 85 percent of the parents and guardians were illiterate. Eighty percent of those surveyed said they had to sit outside the classrooms in their primary schools owing to the observance of untouchability in the villages where they began their education.

There has been a concurrent cultural and literary renascence. The converts refer to themselves as *dalits*, "poor and downtrodden." The *dalit sahitya* (literature of the poor and downtrodden) is compared by Mahar intellectuals to the literature of black Americans. The first imperative of *dalit* writers is to attack and overcome the Hindu Sanskriti, which, one *dalit* wrote, "for thousands of years enslaved the *dalits* and did not even give

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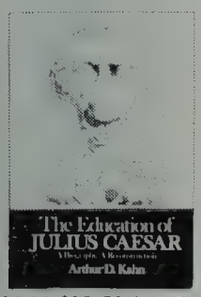

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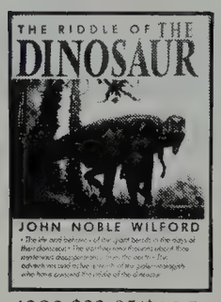

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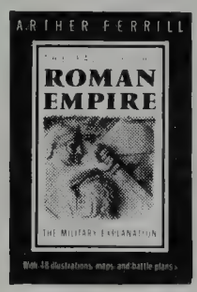

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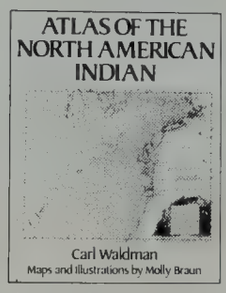

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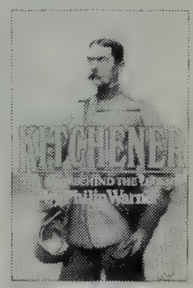

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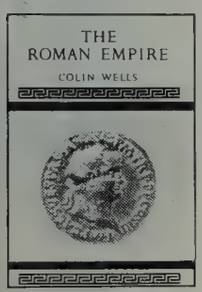

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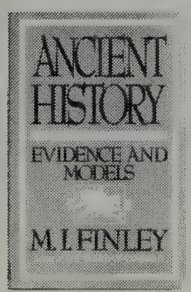

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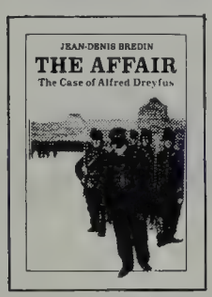

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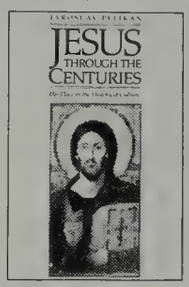

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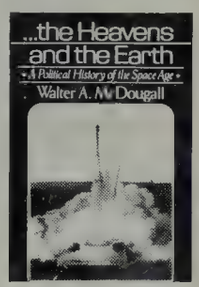

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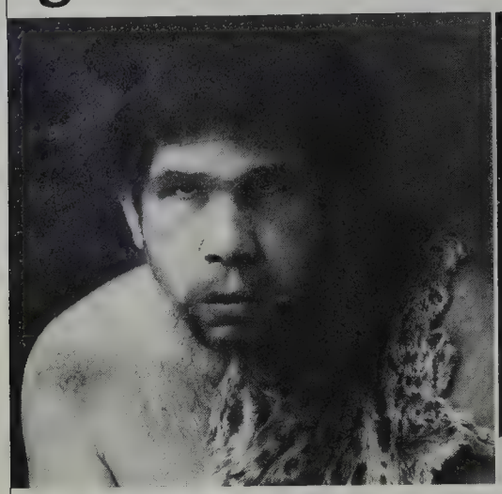

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One of the many dalit *homes destroyed each year in antiuntouchable violence.*

them the right to live as human beings. *Dalit* writings vigorously denounce Hin duism, deride Hindu gods, and expres contempt for superstitions and a hatred o caste. Using local dialects and colloquia isms, the literature is often deliberatel provocative, blasphemous, and obscene At the same time, *dalits* write of the desir to connect their changed lives to the life o the untouchable communities from whic they arose. "My autobiography," write one *dalit*, "is the story of the freedo struggle of the untouchables."

The Buddhist conversion succeeded i removing the blemishes of pollution an restoring to individuals a sense of sel respect and humanity, allowing them t get out from under the encumbrances o caste. Nevertheless, the social relatio ships among lower-caste communitie never strong, have been further strained Buddhist identity has separated th Mahar-Buddhists from other Schedule Castes as well as from caste-Hindus. Th Mangs and the Chambhars, who togethe make up 50 percent of the Schedule Caste communities of Maharashtra, r mained Hindus. Those who did not co vert often saw Buddhism as an affectatio with few deep roots. This suspicion wa compounded by caste-Hindu resentmen at the nonperformance of traditional tas by the converted Mahars. While man

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villagers were glad they no longer had to provide Mahars with grain allowances, they were offended at having to do unclean chores that had previously been left to the Mahars. Hindus were also angry with the new Buddhists for daring to flout Hinduism and no longer accepting their place in the caste hierarchy.

In retaliation, various forms of boycott and harassment were used against the Buddhists. In some villages they were barred from the village streets or from the temple of Mariai, the Mahar deity. After conversion, the temples became community centers for the new Buddhists. In other villages, caste-Hindu farmers ceased plowing or seeding the lands of the Mahars as they had formerly done. In one account, when the Mahars decided not to remove a dead water buffalo, the angry caste-Hindus burned down the Mahars' huts. The increase in tension between the new Buddhists and the caste-Hindu villagers prompted more of the *dalit*s to leave the village.

The unconverted Scheduled Castes reacted against the new Buddhists when they maintained their claim to government job quotas set for once-untouchable Hindus. Recognizing that the Scheduled Castes were a minority that had long suffered from social discrimination, the Indian Constitution set up a special protec-

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tion for them. Quotas reserved seats for Scheduled Castes in educational and government institutions. The Mahar-Buddhists, although no longer untouchables or officially members of the Scheduled Castes, still claimed rights to these reservations. Those who did not convert protested that the Mahar-Buddhists wanted to eat their cake and have it too. To obtain access to the quotas, converted Mahars often deny their Buddhist identities, once again affirming the hold of caste over their lives.

In the cities, the Mahar-Buddhists—with their emphasis on education—now receive a greater share of the government benefits reserved for the untouchable communities. They gain more scholarships and government grants for college and represent the majority of the Scheduled Caste students in Bombay.

In the villages, the Mahars who converted are sharply distinguished from other Scheduled Caste villagers. They are more demanding of their constitutional rights, for which caste-Hindus see them as troublemakers. Demands to use the village well, which are often spearheaded by the Buddhists, have brought violent caste-Hindu reactions. In February 1974, Hindus with night sticks severely beat members of the Buddhist community of Sonavale in Maharashtra when they attempted to draw water from a communal well, after the well reserved for the untouchables had gone dry. In a village in the Poona district of Maharashtra, Mahars were subjected to *bahishkar* (a severe form of social and economic boycott) when they contested the election for the district council with an independent candidate rather than support the candidate proposed by village leaders.

From the late 1960s the incidence of atrocities against the Buddhists increased significantly. The rural police and the civil administration are overwhelmingly in the hands of caste-Hindus (non-Brahmin Marathas in particular), and the perpetrators of the atrocities may get the tacit, if not the overt, support of the law. The demands and pleas of the Scheduled Castes often fall on deaf ears.

Statistics collected by the Ministry of Home Affairs indicate that Maharashtra ranks second among all the states in the number of complaints filed by Scheduled Castes. In the 1970s, some particularly brutal assaults came to light. In a 1972 case, the so-called suicide of a Mahar-Buddhist boy in Nagpur district was discovered to have been a ritual murder. Buddhists are often singled out as targets of violence. In a macabre compilation of atrocities committed against them since

The Hindu caste system as depicted by Gobi David, a dalit *artist. From top: Brahmins; warriors and merchants;* shudras *and peasants; and untouchables.*

independence, a noted Buddhist scholar lists ritual murder, blinding, burning, and rape. These incidents are not confined to villages. A caste-Hindu mob attacked a Buddhist neighborhood in a Bombay suburb in 1974, and a government inquiry concluded that the riot was tantamount to a caste war. Four years later, riots erupted in Aurangabad and rapidly spread into the adjoining rural areas. These incidents arose over renaming Marathwada University, Dr. Babasaheb Ambedkar Marathwada University.

The continuing violence, the latest of which took place just last year in Gujarat and Madhya Pradesh, demonstrates the strength of caste prejudice in Indian society. Despite the proclamation of their Buddhist identity, the converts are still regarded and treated as untouchables by most Hindus. Thirty years has not been long enough to change that. Still, the number of the converted grows. Some five million Buddhists now make up more than 8 percent of the population of Maharashtra. These people call themselves Buddhists despite the personal struggles this commitment often entails. "I am a Buddhist now," wrote one. "I am not a Mahar or an untouchable, not even a Hindu. I have become a human being." □

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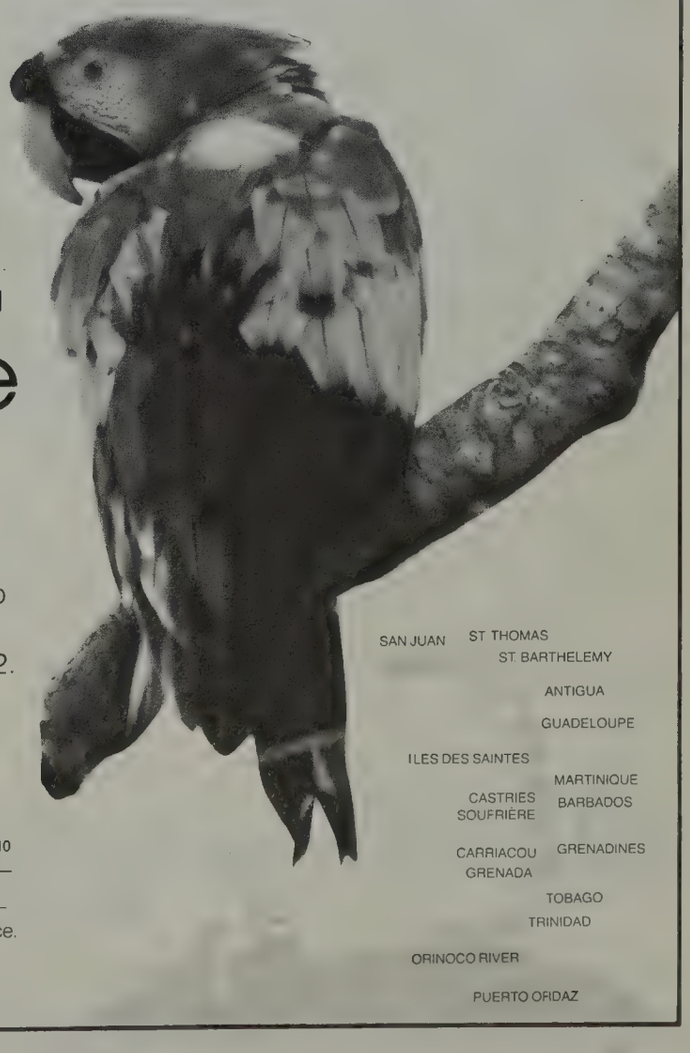

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A blue jay holds a ripe pin oak acorn, which it may crack and eat on the spot or carry off to bury, or cache, for later feeding.

David Neil Parks

Airlifting the Oaks

For long-distance seed transport, neither wind, water, nor roaming mammal can match the blue jay

by W. Carter Johnson and Curtis S. Adkisson

Perceived as greedy and aggressive at bird feeders, raucous in otherwise hushed woods, and rapacious at the nests of other birds, the common blue jay has long provoked criticism. In an 1831 account of marauding owls, naturalist-artist Alexander Wilson launched into a vivid, if anthropomorphic, depiction of blue jays:

> The blue jay himself is not guiltless of similar depredations with the owl, and becomes in turn the very tyrant he detested, when he sneaks through the woods, as he frequently does, and among the thickets and hedgerows, plundering every nest he can find of its eggs, tearing up the callow young by piecemeal, and spreading alarm and sorrow around him.

But such indictments were tempered in the early literature by a recognition of the blue jay's importance to forest regeneration. Naturalist William Bartram wrote to Wilson:

> The jay is one of the most useful agents in the economy of nature, for disseminating forest trees . . . . Their [jays'] chief employment, during the autumnal season, is foraging to supply their winter stores. In performing this necessary duty, they drop abundance of seed in their flight over fields, hedges, and by fences, where they alight to deposit them in the post holes, ... These birds alone are capable, in a few years' time, to replant all the cleared land.

Time has proved the blue jay to be more of a hooligan than a brigand. In a study completed nearly a century ago by F.E.L. Beal, remains of small birds were found in only 2, and the shells of small birds' eggs in only 3, of 292 blue jay stomachs. But although the nest-robbing propensities of jays are not well documented, the birds retain their popular reputation as avian huns. Like any successful omnivore, jays tend to take food opportunistically, and the nesting season provides abundant eggs and nestlings of other species at the time when jays have the greatest need of high-quality food for their own young.

The redeeming tendency of jays to transport and bury nuts and other tree seeds, lauded by Bartram a century and a half ago, is now coming to the fore in the study of tree dispersal. Two developments have stimulated scientific interest in seed

transport by blue jays. The first is landscape ecology. This new science examines species diversity—the number and range of plants and animals within a habitat—particularly where the growth of cities and farms has led to the fragmentation of formerly vast forests. In an area we have studied in southeastern Wisconsin, for example, wooded tracts have been cleared to make way for fields and cities. Because the trees that remain are found in isolated patches, now mere parts rather than a whole, the ecology of the once-continuous forest has been disrupted. The dispersal by blue jays of large numbers of heavy seeds, such as acorns and beechnuts, among these separate ecological "islands" may help to maintain plant diversity by offsetting the effects of physical isolation.

The importance of the dispersal process is not limited to modern landscapes. New discoveries in the field of biogeography have drawn attention to the jay. During the last Ice Age, North American glaciers supplanted northern vegetation, and deciduous trees such as oaks, beeches, and chestnuts were pushed south. The end of the Ice Age, about 10,000 years ago, saw a return north of these hardwood species. Hazel R. Delcourt and Paul A. Delcourt have located the glacial refuges of these trees in the southeastern United States, where warm gulf coast air and accumulations of rich loess soil created "corridors" of good hardwood habitat along southeastern river systems such as the Mississippi. Until recently, biogeographers believed that heavy-seeded trees, such as oak, returned slowly from these pocket refuges. However, oaks are now known to have quickly migrated north after the retreat of the glaciers, even faster than some trees with light, windblown seeds. The oak's rapid spread cannot be explained by mammals transporting acorns, because mammals such as squirrels seldom carry seeds much beyond the parent tree. In view of these findings, the most likely candidate for the role of long-distance acorn disperser, both past and present, is the blue jay.

Our studies over the last several years in Virginia and Wisconsin have taught us that in late summer and early fall jays from a wide area congregate in wooded patches that include oaks and beeches. The birds hammer into some of the soft-shelled nuts and eat their contents but collect many others that they transport undamaged back to their territories, where they cache them in the ground. Where nut-bearing trees are especially concentrated, jays stream in and out of the

David Neil Parks

A jay appears to swallow a green acorn, left, but the nut will later be disgorged and buried. The bird's throat and esophagus expand to accommodate several pin oak acorns. Cached acorns left unretrieved by spring have a good chance of sprouting into oak seedlings. Opportunistic feeders, jays eat a variety of plant and animal food, including insects, fruits, nuts, and seeds. The jay below grasps a slender seed in its feet and splits the husk with its bill. Tougher seeds, such as acorns, are hammered open.

Stephen J. Krasemann; DRK Photo

woods. They fuel these energy-demanding flights by devouring a quarter or so of the nut crop within a patch of trees. Each jay undertakes hundreds of such round-trip flights each fall.

In suburban environments, where nut trees are often abundant, distances between food sources and home territory may range from a few yards to a mile. But in heavily deforested regions like southeastern Wisconsin, where forest patches are separated by extensive fields, we recorded round-trip flights of five miles for marked birds. If these birds make ten round-trips per day, each will travel about 1,500 miles during a single fall month. Jays living in northern regions make flights as demanding as these during two other major periods of energy expenditure—the annual molt and the fall migration. Both migrant and resident populations of jays engage in caching. Jays that migrate probably return in the spring to their home territories to use nuts cached the previous fall. When jays undertake long-distance flights in the fall, they risk predation by migrating hawks. The additional baggage of seeds reduces the jays' speed and hinders their ability to maneuver. When crossing open land, jays partly offset the risk by flying near escape cover, such as that provided by fencerows and hedges. We have often seen jays diving into thick vegetation upon the approach of a hawk.

Jays have catholic tastes in soft-shelled nuts. They probably disperse, at one time or another, the nuts of all of the thirty or so species of oaks in the deciduous forests of eastern North America, not to mention wild pecans, beechnuts, and before a fungus wiped the species out, American chestnuts. These seeds range from the pea-sized nuts of willow oak and beech to the thumb-sized nuts of northern red oak and wild pecan.

An expandable throat and esophagus allow the jay to transport as many as three white oak acorns or five pin oak acorns or fourteen beechnuts per trip. After filling its throat, the jay often collects one last nut in its bill before departing. Some jays transport two extra beechnuts per trip by plucking a beech bur, containing two nuts, before flying off. The bird positions the bur so that it projects in front of the bill, a habit that may serve to minimize drag during flight.

Foraging on nuts also requires specialized structural adaptations. A modified articulation of the lower jaw prevents backward unhinging of the mandible when the bird pounds hard foods to crack them open. The lower jaw does the pounding while the bill is kept slightly open. The reinforced skull can withstand repeated blows. These adaptations work in conjunction with the jay's grasping feet, which secure the nuts being hammered open.

Contrary to Bartram's anecdote, jays do not drop seeds from the air and alight to cache them. Rather, upon arrival in its territory, a jay disgorges the nuts into a pile on the ground. It then selects a single nut and either hops or flies a few yards to a caching spot, where it hides the nut by pushing it into soft soil or tucking it under grass. Then the bird returns to the pile and repeats the procedure. In some cases, jays disgorge the nuts and hop about caching them one by one in separate parts of the caching area. Caches are always covered with plant debris the jay collects nearby. The covering or burying of caches probably reduces the chances that the seeds

R. Hamilton Smith

Once-extensive hardwood forests, carved up into patches by encroaching farmland, left, benefit from the reforestation that is a byproduct of blue jay nut caching. A throatful and beakful of acorns hardly disrupt the streamlined appearance of a jay in flight, below, but the extra weight can encumber the bird and hamper aerial maneuvers needed to evade predatory, migrating hawks in the fall.

W. Carter Johnson

will be found and eaten by other animals and may enhance germination and early growth of the seedling by protecting the seed and emerging root from drying out.

Enormous quantities of nuts are moved by jays each fall. At our study sites in Blacksburg, Virginia, our associate Susan Darley-Hill discovered that in twenty-eight days about fifty jays transported and cached 150,000 acorns, 58 percent of the total nut crop from eleven pin oak trees. Nearly all of the nuts remaining on the ground had been destroyed either by jays themselves or by weevil larvae. In rural Wisconsin, we found that an equally large number of beechnuts were dispersed from a single wood lot.

Blue jays select and cache sound nuts most likely to sprout and grow. We found that the germinability of beechnuts dispersed by jays (88 percent) was much higher than that of nuts we collected at random from the same trees (10 percent). Other corvids—the family that includes crows and nutcrackers as well as jays—are able to discriminate between viable and unsound nuts by holding or rattling nuts in their bill. Unsound nuts are simply dropped beneath trees.

Nuts cached in the fall are retrieved and eaten during winter and early spring, when high-energy fare (such as insects and certain fruits) is scarce. Corvids such as European jays and Clark's nutcrackers of the American West are known to find their buried stores by remembering many of the hundreds of cache locations; nut retrieval is easier when caches are situated near "beacons," such as small trees, rocks, sidewalks, or fences, a propensity alluded to by Bartram. Studies of other corvids indicate that a large surplus of nuts is stored but that many of these extras are discovered and eaten by small mammals. Caches never retrieved by birds and undiscovered by mammals lead to the regeneration of trees and the eventual perpetuation of nuts for future generations of blue jays. The many species of nut trees tend to produce their seeds in different years. This staggered production greatly reduces the likelihood of a complete nut crop failure and makes soft-shelled nuts a reliable food source.

Blue jays and oaks thus mutually benefit from the bird–nut connection. Jays take advantage of a relatively dependable, nutritious, and durable source of food. New trees sprout from viable seeds transported to well-lighted locales that favor germination and early growth. The relationship between jays and oaks is not exclusive. Other animals also disperse nuts, and jays eat many other kinds of seeds and

F.J. Alsop III; Bruce Coleman, Inc.

Below: Loading up for a transport, a jay holds two acorns in its bill and others in its throat. Blue jays also carry beechnuts, wild pecans, and the nuts of as many as thirty other oak species. Right: A parent jay tends its brood. Jays that plunder other nests for eggs and young are then able to feed their own nestlings on the high-protein fare.

David Neil Parks

fruits. But the persistence of the relationship attests to its strength.

Because blue jays make choices about what nut species to cache and where, they may well influence the basic structure of ecological communities. This form of seed dispersal contrasts with the indiscriminate scattering of seeds passing through the gut of an animal or borne on the currents of wind or water. Thus, the distribution of oaks in nature may mirror the collective behavioral decisions made by the community of jays as they select, disperse, cache, and retrieve nuts. Nut dispersal by jays is especially important where forests are reduced to patches isolated by grassland, farmland, or highways, all of which may hinder the movements of small seed-dispersing mammals. Furthermore, the ease with which jays move about in human-dominated landscapes fosters oak regeneration in old fields, vacant lots, fencerows, and other untended land isolated from seed-bearing oaks.

We believe that blue jays could easily have filled the role of postglacial oak disperser. The rate at which oaks advanced north 10,000 years ago—about 380 yards per year—surpasses even that of spruce trees, which with their light, wind-borne seeds, travel relatively quickly at about 270 yards a year. Our calculations, based on the age of reproductive maturity of oaks, suggests that nut dispersal distances of several miles are required for an average migration rate of 380 yards per year. This matches the maximum dispersal distances we observed in our field studies, but jays may easily carry acorns even farther. Clark's nutcracker, a jay relative, carries pine seeds up to fourteen miles to caching sites. Thus, after the Ice Age, blue jays could have nested in young, oakless forest patches, to which they are well suited, and there could have cached nuts they collected from mature oaks a few miles to the south.

Our findings indicate that ecosystems, particularly those undergoing regeneration, benefit from blue jay nut caching. Indeed, blue jays thrive in disturbed ecosystems and promote proliferation of trees that otherwise are only locally dispersed. Recognition of the blue jay as a benefactor, despite its brigandly ways, and wise use of our knowledge of jays and oaks may one day help in the recovery of unreclaimed strip mines, scorched land, and eroded forests. Some 150 years ago, Bartram credited jays with the ability to restore "all the cleared land." In the 1980s, the blue jay may prove to be a valuable ally in the big job ahead. □

11 30 am. Cast off from the Jetty, in Portsmouth Harbour, and with
commenced our voyage of Scientific exploration and Circumnav
for a wonder the sun shone out first as we started and remained
we discharged our Pilot and a few friends to the Tug which h
accompanied us out as far as Spithead. These good people d
their best to enliven our departure - and we were greeted with th
cheers as they shoved off. and immediately afterwards we pro
for the Needles. The lively proceedings of the ships crew soon
developed, for even before we reached the Needles - signs of moder
were observable, and made me anxious to get everything secu
as quickly as possible - precautions which were soon to be four
necessary. as a falling Barometer and northward looking sun
gave very indication of a gale from the SW. In the first watch
became thick - and plenty of drizzle - at 2.30 am. we got a gl
of the Start Light abeam - and lost
sight of him 2 hours afterwards.
The 22nd opened with a fine
light sunshine - the wind having
veered gradually from West
round to the Southward
moderate breeze. to which
we made all Plain Sail
Main Royals and F. Lib.
Tacking convenient to W.S. to keep
a good Weather in case of falling
in with the expected SW. Gale. — At Midnight the wind and
began to increase - and necessitated a gradual shortening of s
until 4am found us under Topsails on the Cap and Courses —
in a nasty confused sea - and the Ship was uncomfortably mov
rolling 22° to Starboard and 16° to Port, with a few hints that she
and would ultimately do more - The Barometer still fell steadily
and the ship was kept rather full in the first Watch to make Westing
as we should to the SW. — A lively day promised - under close reef
Topsails and
Jib & SSW.
Staff Sails with heads hauled in - a fresh Gale fro
the ship rolling 35° to Leeward - During the
the Bar fell and the wind rose. Noon in the
& getting wind from NW. but Barom would n
the wind never getting further round than W
W. SW to WSW. a heavy Sea running and ship knocking about a gre
At - The first night in a gale of wind always produces a few "m

A page from the log of H.M.S. Challenger
Royal Geographical Society

Mappers of the Deep

How two geologists plotted the Mid-Atlantic Ridge and made a discovery that revolutionized the earth sciences

by Marie Tharp and Henry Frankel

Editor's Note: Only a few decades ago, most scientists ignored or rejected the ideas of continental drift and plate tectonics. Today, they accept these theories and use them to explain the earth's face, its movements, and its history. Continental drift, paleontologists now realize, has also played an immense role in the distribution of life on the planet.

Such great revolutions in scientific thought almost never arise from a single scientist, a single discovery, or even a single research facility. Yet discoveries do seem to emerge—by accident, by luck, and by different forms of genius—at a particular time and place. In this case, the place was the Lamont-Doherty Geological Observatory of Columbia University at Palisades, New York; the time was the early 1950s; the discovery was the unexpected length of the Mid-Atlantic Ridge and its surprising features; the major characters involved were Bruce Heezen and Marie Tharp. Heezen died in 1977. Marie Tharp discussed the events and supplied notes to science historian Henry Frankel, who coauthored this essay.

Soon after the end of World War II, an increasing number of geologists and geophysicists began investigating the sea floor. Within twenty-five years they turned it from an area about which scientists were ignorant into one of backyard familiarity. Little was known about the sea floor during the 1950s and 1960s but interest and support were strong, so oceanography was tremendously exciting, and the chances of making a major discovery were great. Bruce Heezen, then a graduate student in geology at Columbia University, and I, a graduate geologist, were working at Columbia's Lamont (now Lamont-Doherty) Geological Observatory when we made such a discovery—the central rift valley in the Mid-Atlantic Ridge.

In 1952, I became convinced of the valley's existence along a segment of the ridge. Within about six months Bruce agreed and began to wonder about its significance. But it took four years before our discovery was published as an abstract by Maurice Ewing and Bruce. (Ewing at that time was the director of the Lamont Observatory.) Bruce and I had a great deal of fun during those years, and this is an account of how the discovery came about.

Fathoming of the deep sea did not begin until Matthew Fontaine Maury (1806–1873), the colorful and dynamic director of the U.S. Naval Depot of Charts and Instruments, produced, in 1854, a contour map of the North Atlantic on the basis of about 200 hemp and lead sinker soundings. He identified a higher middle ground in the North Atlantic, which he called the Dolphin Rise. This was the first identification of what later became known as the Mid-Atlantic Ridge.

In 1872, the British ship H.M.S. *Challenger* began a four-year research voyage. Charles Wyville Thomson (1830–1882), a professor of natural history at Edinburgh, headed the expedition. Thomson took soundings every 100 miles on several crossings of the Atlantic with a 200-pound lead sinker on a hemp line. He noticed a difference in the water temperature on either side of the Dolphin Rise and reasoned that it acted as a barrier to the flow of deep ocean currents. The tracks, or paths, he made extended the rise down through the South Atlantic. His soundings confirmed the existence of the plateau but could not differentiate between a mountainous ridge and a broad, smooth rise.

'In 1947, Ewing needed seagoing technicians to whom he could offer adventure in lieu of pay . . . if they were interested in geophysics and geology, all the better.'

It was not until the German *Meteor* expedition (1925–1927), a water cruise that plotted currents, measured temperature and salinity, and took soundings every five to twenty miles, that the elevation in the mid-Atlantic was revealed as a rugged mountainous ridge running down the center third of the South Atlantic. The Germans made this determination through the use of the "stop watch" method, which measures the lapsed time between an acoustical signal and its echo—the signal bounces off the ocean floor and returns to the ship as an echo.

Although the *Meteor* expedition received wide publicity in the popular press, and students of oceanography were excited about its findings, the detailed results of the cruise, published in German in several volumes, remained an untapped source of information for many years. Nobody, for example, ever bothered to connect all the "holes" found in the numerous sounding profiles along the crest of the ridge. If someone had made the connection, the central rift valley might have been discovered then and there. But the *Meteor* expedition, being primarily concerned with sea water currents and the properties of temperature and salinity, did not bother with the ocean floor.

In 1947, Maurice ("Doc") Ewing, then a newly appointed member of the Geology Department of Columbia University, undertook a Sigma XI lecture tour with the avowed purpose of finding bright graduate students to work in oceanography. Actually, what Doc really needed at the end of the 1940s, before funding became abundant, was a group of seagoing technicians from affluent families to whom he could offer a life of adventure in lieu of pay. Of course, if they were interested in geophysics and geology, all the better.

Ewing described taking seismic refraction profiles on the Southern Bermuda Rise—these are cross sections through layers of sediment down to the sea floor, made by setting off bombs in the water behind a ship that is under way at full speed and timing the returning echo. The process involves short fuses and lots of explosives. After hearing Ewing's lecture on these perilous techniques, Bruce Heezen, who at that time was an undergraduate geology major at Iowa State University, came up to meet the speaker. Whereupon

Doc Ewing said, "Young man, would you like to go on an expedition to the Mid-Atlantic Ridge? There are some mountains out there and we don't know which way they run." Bruce was somewhat startled. His professor Arthur Trowbridge said, "Of course he would like to go!" Bruce went, and spent the next thirty years working on problems connected with the sea floor. Over the next two years, Doc Ewing and Bruce participated in three expeditions to the Mid-Atlantic Ridge, each aboard the *Atlantis I*, the major oceanographic research vessel belonging to the Woods Hole Oceanographic Institution. The expeditions, jointly sponsored by Woods Hole, Columbia University, and the National Geographic Society, surveyed the ridge with an echo sounder that operated continuously while the ship traversed the ridge at random angles. The development of this nonstop echo sounder was extremely important, for it provided us with uninterrupted profiles—something that the *Meteor* expedition did not do. With this new technology, the amount of data in a profile no longer depended on how often the ship stopped at a station to take an echo sounding. But the device had one disconcerting drawback: it depended entirely on the ship's irregular and intermittent electric power, which went off whenever someone opened the ship's refrigerator. When that happened, no echo returned; instead, the sounder recorded measureless depths. At mealtimes the ocean floor became as bottomless as the crew's appetite.

In 1952, Bruce turned to the question of the topography of the Mid-

Marie Tharp

Bruce Heezen on the deck of the Atlantis I, *working with oceanographic equipment. The ship was on loan to Lamont from the Woods Hole Oceanographic Institution.*

Atlantic Ridge. I had gotten my job at Columbia University in 1948 by managing to know a little about a lot, after picking up a B.A. at Ohio University, a master's degree in geology at the University of Michigan, and a B.S. with a major in mathematics at the University of Tulsa. I was hired at Columbia by Doc Ewing, officially as a research assistant, but in practice I became a helper for graduate students and worked in the basement of Schermerhorn Hall. At first, I worked for anyone who needed me, but after a few years Bruce kept me so busy that I worked exclusively with him, drafting and plotting ocean profiles. He had interminable rows of sounding numbers plotted into graphs, or profiles, whose coordinates were depth and distance. The vertical coordinate was depth in fathoms (one fathom is six feet); the horizontal coordinate was distance in nautical miles (one nautical mile is 6,000 feet). I was supposed to turn the rows of numbers into a set of highly detailed and complete profiles.

In 1952, after about six weeks of plotting, matching, and gluing, I completed six transatlantic profiles. I pieced together sections of data from eight cruises in order to make a more understandable set of west–east profiles from south to north in the North Atlantic. The ratio of the vertical to the horizontal coordinates was 40 to 1, and the continental margins, ocean basin floor, and Mid-Atlantic Ridge were shown between North America and Europe, South America and Africa.

Besides the general similarity in the shape of the ridge in each profile, I was struck by the fact that the only prominent matchup apparent when I compared the profiles was a V-shaped indentation located in the center of each. The individual mountains didn't match up, but the cleft did, especially in the three top, or northernmost, profiles of the North Atlantic. Thus it seemed to me that the V-shaped indentations represented cross sections of a valley that

Earthquake epicenters in the North Atlantic fall along the crest of the Mid-Atlantic Ridge. This was known as far back as 1944. What was not known then was that the ridge contained a rift valley—a fault created by earthquakes.

Geological Society of Americ

into the ridge at its crest and continued along its axis. Of course, I didn't w about the remainder of the ridge—the area beyond the most northerly southerly profiles—and the V-shaped indentation was only obvious in the three profiles.

told Bruce what I thought and showed him the matchup in the position of valley in the top three profiles and possible extensions into the other three. ce didn't think the matchup was so obvious. He groaned and said, "It not be. It looks too much like continental drift." This was just about the st thing he could have said, since at the time, he and almost everyone else amont, and in the United States, thought continental drift was impos-e. North American earth scientists considered it to be almost a form of ntific heresy, and to suggest that someone believed in it was comparable aying there must be something wrong with him or her.

f there was such a thing as continental drift, it would have had a connec- with a midocean rift valley. If drift did indeed exist, the valley would e been formed where new material came up from deep inside the earth, tting the midocean ridge into two and pushing the sides apart. That, in , would move the continents resting on their various tectonic plates.

ome time after I had finished plotting the six profiles, I told Bruce my about the existence of a valley. Then one day we decided, quite suddenly, ake a physiographic diagram of the ocean floor. Unlike flat contour maps do not bring out the three-dimensionality in pictorial form, physiographic grams look three-dimensional. They show the terrain as it would look from w-flying plane. After an hour or so of scribbling, Bruce produced our first siographic diagram. By 1952, he had been on enough cruises to enable to discover most of the features of the western Atlantic.

lthough he was somewhat unhappy with the results of his efforts and ed me to do the diagram over, both of us were pleased with the technique. hat time, however, detailed contour maps of the ocean floor were classi- by the U.S. Navy, so we had to find another way of presenting our data. kaging our information in the form of physiographic diagrams not only ed our publication problem but also provided a much more natural ure of the sea floor. The diagrams allowed us, for example, to capture the floor's many textured variations, contrasting the smoothness of the abys- plains with the ruggedness of the mountains along the ridges. In 1961, r contour maps of the sea floor were declassified, we decided to stick with physiographic diagrams.

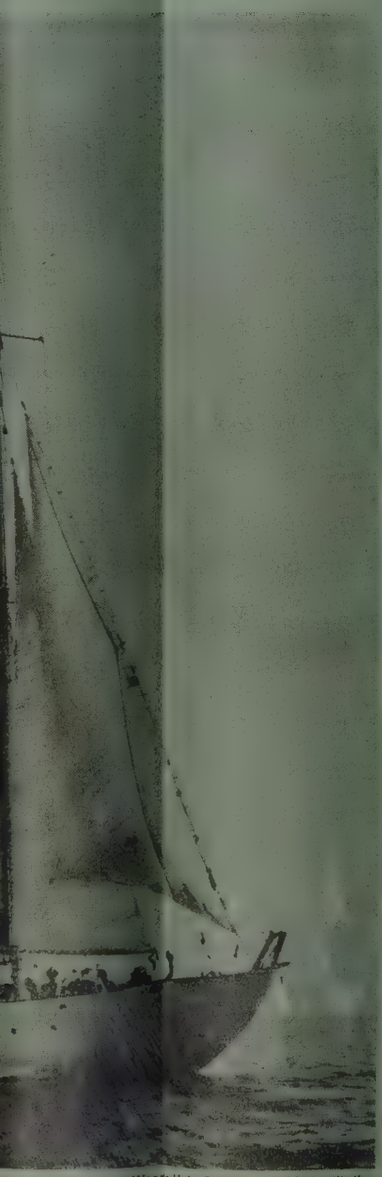
During the time I was working up the profiles and starting the physio- phic diagram of the North Atlantic, Bruce was busy on another project. and Ewing had confirmed the existence of turbidity currents and umented the great speeds these currents had attained when they caused breakup of a series of transatlantic cables during the 1929 Great Banks hquake. Bell Laboratories was contemplating laying new cables and ted Bruce to determine the best place to lay them. Cables are costly to lay maintain, and Bell Labs therefore thought the study worth supporting. It , but primarily for reasons initially unknown to them or to us.

Bruce hired Howard Foster, a young, deaf graduate of the Boston School of e Arts who did all his work by hand (since the age of the computer had not

The steam-powered German research vessel Meteor

Atlantis I *under way*

AMNH Archive



Woods Hole Oceanographic Institution

yet arrived), to plot the location of recorded earthquakes in the Atlantic and other parts of the world. He plotted tens of thousands. The records weren't as accurate as our own topographical data, and Bruce complained that the scatter of one to several hundred miles in the positions of the plotted earthquake epicenters "was absolutely abominable" compared with our topographical data of the sea floor.

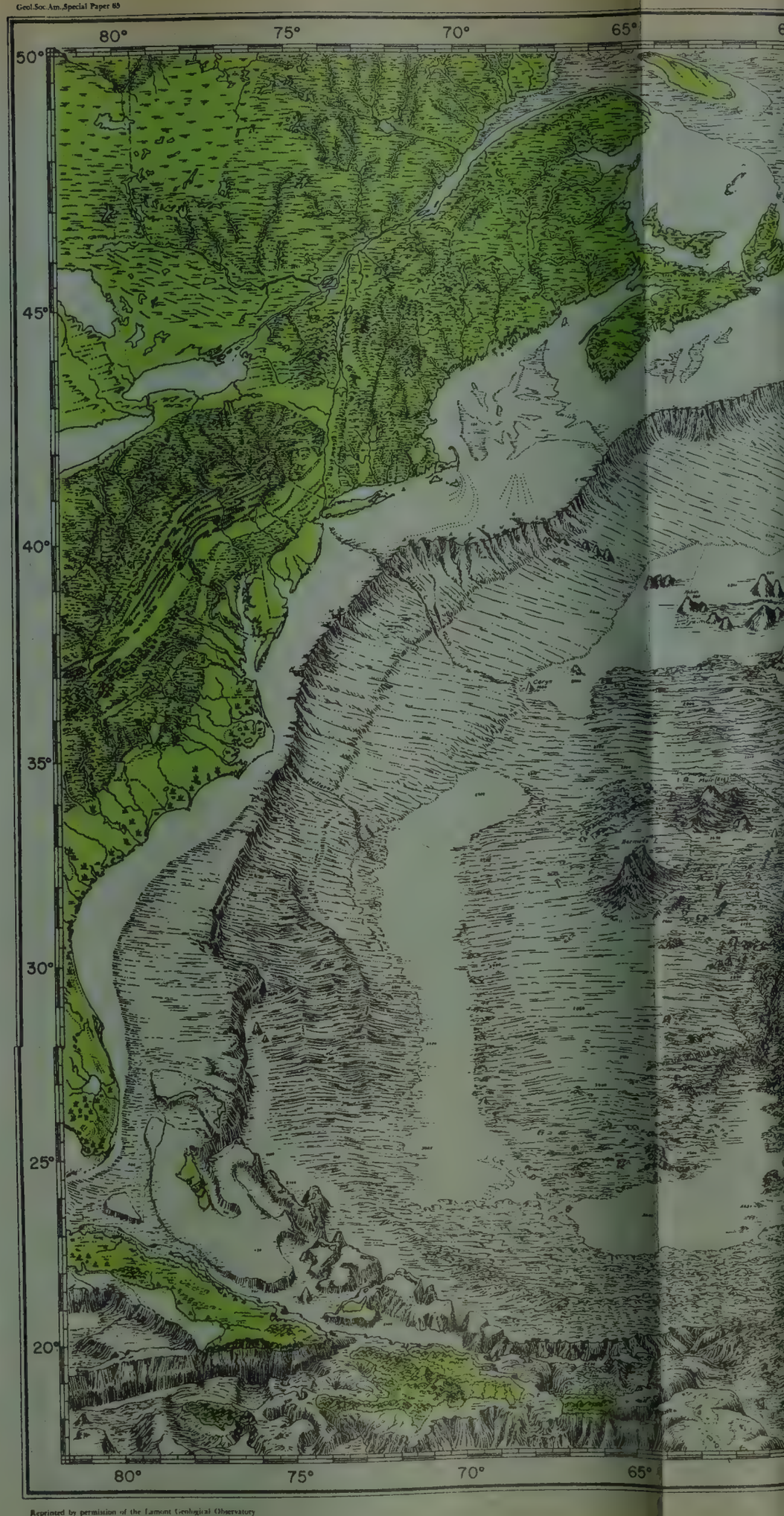
While I was at my map table plotting the position of the Mid-Atlantic Ridge and the alleged valley, a map of the same scale as mine, showing the position of the earthquakes, sat on an adjoining table—Bruce always insisted that all our oceanographic data be mapped at the same scale. He noticed that a line of epicenters from shallow-focus earthquakes ran down the center of the Mid-Atlantic Ridge. This, in itself, was nothing new, for we were aware that two seismologists, Beno Gutenberg and Charles F. Richter, had already noted in their widely read book, *Seismicity of the Earth* (published in 1944), that an active belt of shallow earthquakes "follows the Ridge very closely." (Richter, incidentally, devised the scale bearing his name that measures the magnitude of earthquakes.) But we found more: taking into account the inaccuracy of the plotted positions of the earthquake epicenters, Bruce saw that they fell within the valley. Because all our data were on maps of the same scale, the locations of the epicenters within the valley showed up when we superimposed the maps on a table lighted from below. At that point, I was completely convinced that the valley was real. We had a definite association of topography with seismicity. Although Bruce remained somewhat skeptical, he began to pursue the idea in earnest.

We also knew that Gutenberg and Richter had observed how the shallow earthquakes along the Mid-Atlantic Ridge extended into the Arctic Ocean; how the Carlsberg Ridge in the Indian Ocean and the Albatross Plateau in the Eastern Pacific, like the Mid-Atlantic Ridge, are associated with shallow-focus earthquakes; and how the epicenters of this earthquake belt along the Carlsberg Ridge extended through the Gulf of Aden into Africa along the East African Rift Valley. At this time there were many more recorded shallow earthquakes in the sea floor than there were deep-sea soundings, and many of the earthquakes had occurred along belts where no soundings had been made. This led Bruce to wonder if the isolated oceanic ridges might not all be part of one feature, a gigantic 40,000-mile-long Mid-Oceanic Ridge system.

Just as his predecessors had extrapolated the existence of the southern extension of the Mid-Atlantic Ridge from the differences in temperature between deep-sea currents on both sides of the Atlantic, Bruce reasoned that deep-sea soundings would reveal a ridge wherever shallow earthquakes had occurred. But he still wasn't ready to suppose that future deep-sea soundings would also reveal that the shallow earthquakes occurred within the confines of a central valley running down the axis of this vast ridge system. He didn't accept that supposition until mid-1953, about eight months after I had finished working up the first set of six profiles.

Bruce keyed in on the terrestrial extension of the hypothesized oceanic-ridge system—the rift-valley system of the East African Plateau. He reasoned that since the system of rift valleys in east Africa appeared to be a

'And like cartographers of old, we put a large legend in the space where we had no data. I also wanted to include mermaids and shipwrecks, but Bruce would have none of it.'



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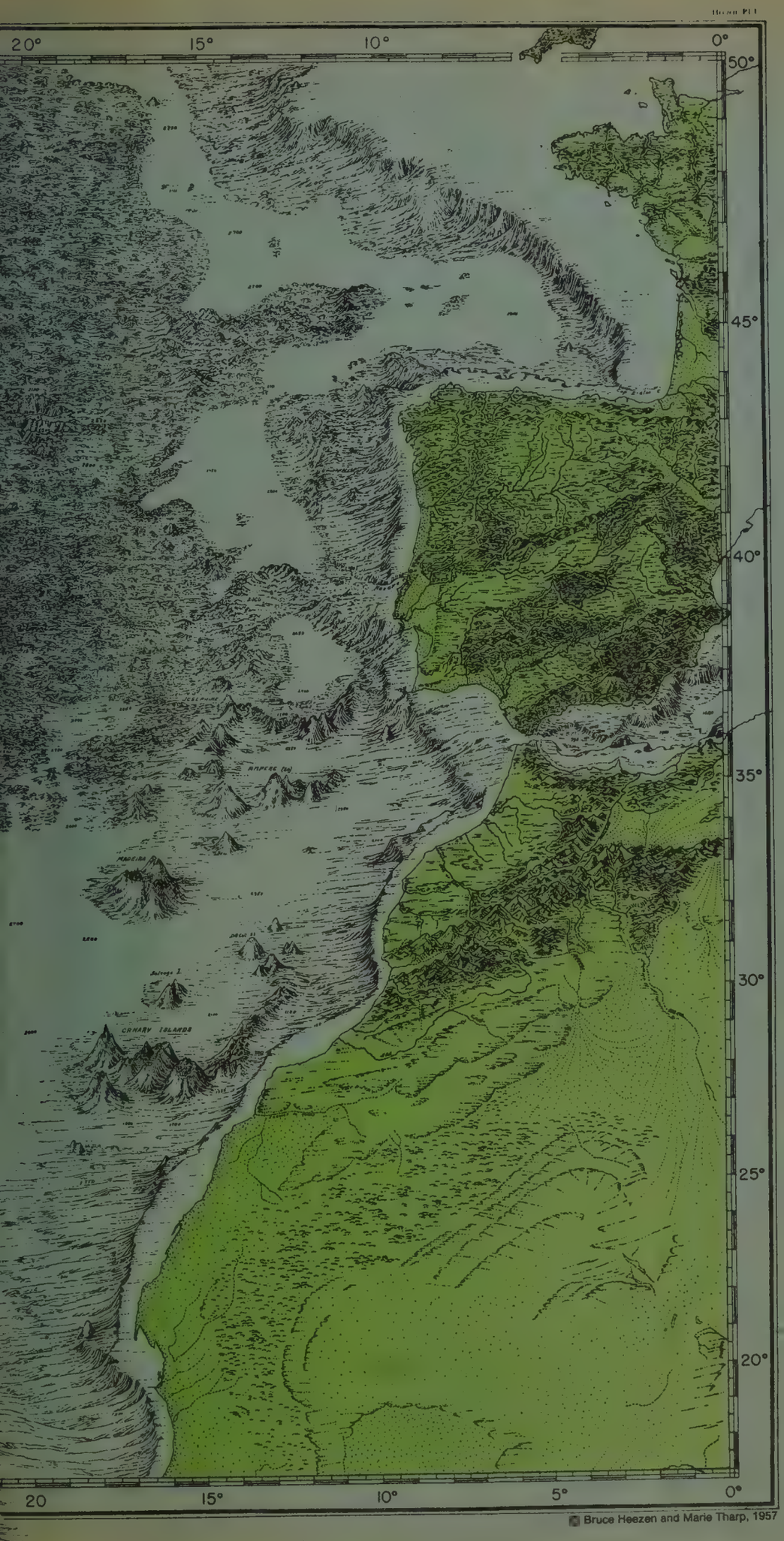
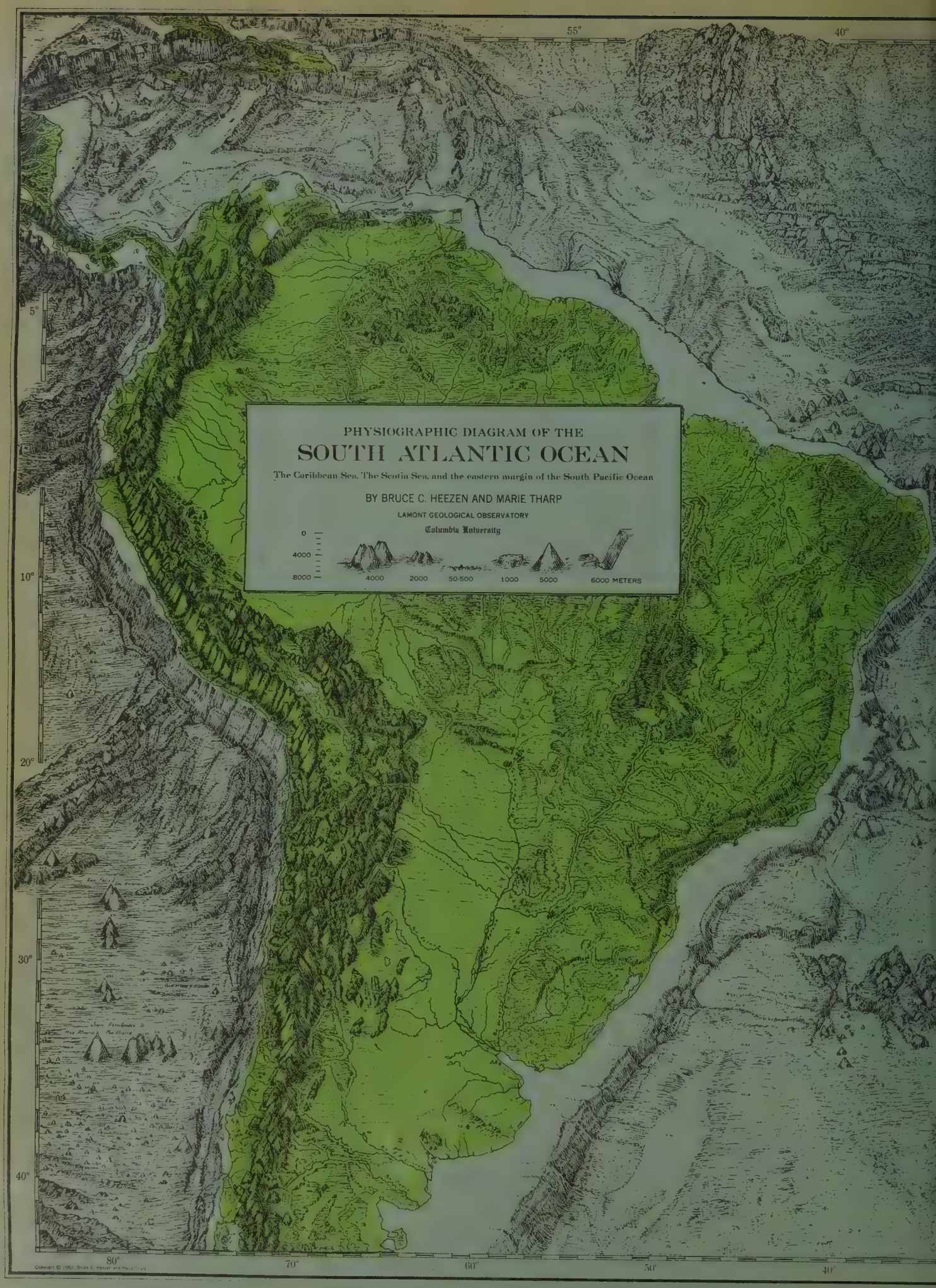
PHYSIOGRAPHIC DIAGRAM
ATLANTIC OCEAN
(Sheet I)
BY BRUCE C. HEEZEN AND MARIE THARP
Vertical Exaggeration About 20:1
20-200 Fathom Relief
200-500 Fathom Relief
500-1000 Fathom Relief
1000-1500 Fathom Relief



The first physiographic diagram of the Atlantic, left, was tossed off in 1957. Heezen was not entirely satisfied with the effort but was pleased with the technique and asked Tharp to rework the data. She and Heezen then made a more detailed study of the Mid-Atlantic Ridge system. The diagram on the next page, drawn with a crow quill pen, showed the extension of the ridge through the South Atlantic and the striking parallelism of the rift valley and the continental margins of South America and Africa. The ridge occupies the center third of both the North and South Atlantic.


PHYSIOGRAPHIC DIAGRAM OF THE
SOUTH ATLANTIC OCEAN
The Caribbean Sea, The Scotia Sea, and the eastern margin of the South Pacific Ocean
BY BRUCE C. HEEZEN AND MARIE THARP
LAMONT GEOLOGICAL OBSERVATORY
Columbia University
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6000 METERS
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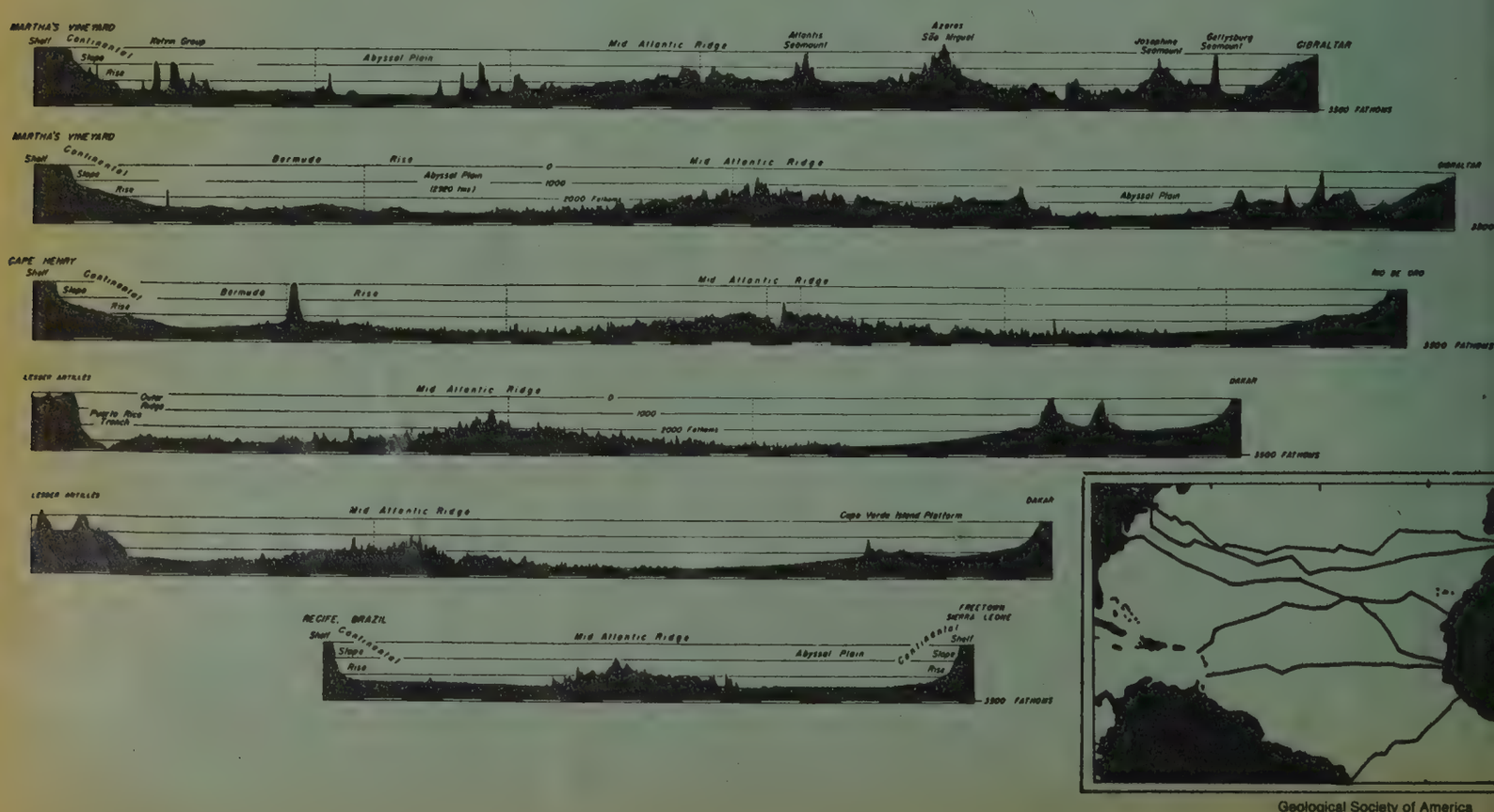
© Bruce Heezen and Marie Tharp, 1961

landward extension of the oceanic-ridge system, he could learn about the oceanic part by studying the terrestrial. I made up profiles of some of the valleys in east Africa. Bruce noted the topographical similarities between the two sets of profiles: one across the ocean; the other across the land. He also saw that the belt of shallow earthquakes associated with the system of east African rift valleys stayed primarily within the confines of the valley walls. He decided to make the jump and endorse the existence of a central valley within the ridge itself that extended along the entire axis of the Mid-Oceanic Ridge system. As far as Bruce was concerned, the tightness of the analogy between the terrestrial and oceanic segments of the ridge system was the clincher. Before, even with the seismic data, he was not sure if the valley's presence on the original six profiles and other oceanic ones that we found was an accident or indicated a real feature of the ridge. Bruce stressed the importance of the analogy by calling the oceanic valley a rift valley, borrowing the term rift from the characterization of the African valleys as rift valleys. And with the "rift" designation came Bruce's suggestion that the central rift valley, whether in the oceanic or terrestrial part of the overall ridge system, was a huge tension crack in the earth's crust caused by a splitting apart of the earth's crust.

During the next few years we displayed our expanding knowledge of sea-floor topography on globes and maps. We prepared several globes showing the physiographic provinces of the oceans, the location of sediments, and the globe-encircling Mid-Oceanic Ridge system with its bisecting rift valley. By 1956 we finished our first detailed physiographic diagram of the North Atlantic. And like the cartographers of old, we put a large legend in the space where we had no data. I also wanted to include mermaids and shipwrecks, but Bruce would have none of it.

Bruce told Ewing of our discovery soon after he accepted it himself. Doc



Tharp put together six profiles from early cruises. When superimposed one on another, a V-shaped identation in their centers appeared to match up, suggesting that a valley ran along the length of the Mid-Atlantic Ridge. The inset shows the six profiles across the ocean; the heavy line in the center indicates the location of the rift valley.

Geological Society of America

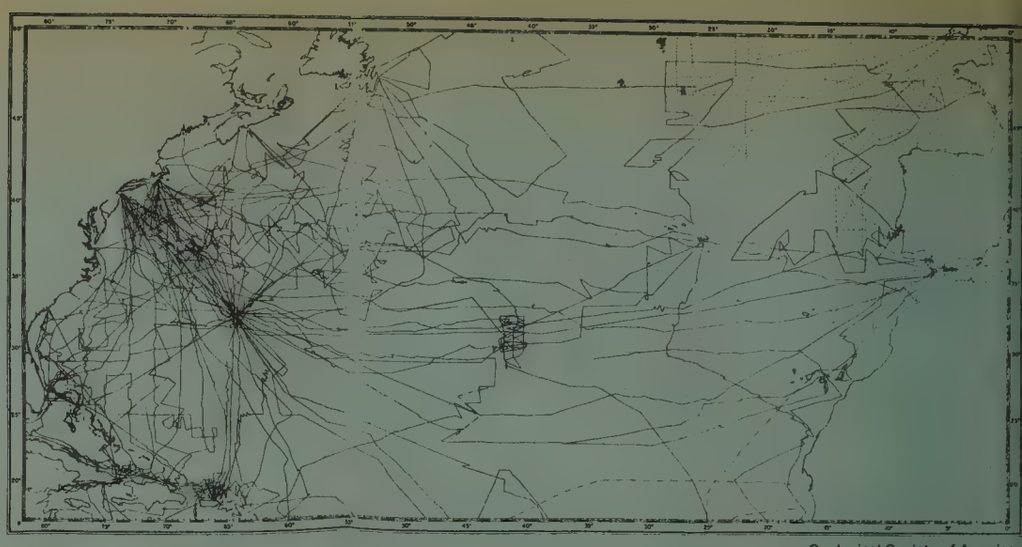
Peter Goldberg

An early Heezen and Tharp globe shows the Mid-Atlantic Ridge and its rift equidistant from the continents bordering the ocean

was interested and would occasionally come around and ask me, "How is the gully coming?" But the knowledge of the existence of the rift valley remained within the confines of Lamont until February 1956, when Bruce first presented the idea at a symposium organized by Harry Hess, professor of geology at Princeton University, for the National Academy of Sciences. Bruce brought along one of our globes with the rift valley outlined in bright red. The valley was at least on our globe, if nowhere else, and hard to miss. Hess was impressed and invited Bruce to Princeton to elaborate on the discovery. The first published account of our find, the abstract already mentioned, did not appear until 1956 at an American Geophysical Union meeting in Toronto, at which Ewing and Bruce announced the discovery of a seismically active rift zone at the crest of the Mid-Atlantic Ridge and its extension into the Arctic and Indian oceans and African rift valleys. We also thought that the rift valley was associated with material that was highly magnetized.

'Bruce brought along one of our globes with the rift valley outlined in bright red. The valley was at least on our globe, if nowhere else . . .'

Ewing and Bruce had begun taking magnetic measurements of the sea floor as early as 1948, when Ewing had Bruce tow an airborne magnetometer (an instrument for measuring magnetic forces) behind the *Atlantis I*. At first they were unable to associate any of the magnetic anomalies with a definite topographical feature, for among other things, there were questions about the reliability of the data. They thought, however, that the crest of the ridge might be associated with a large positive magnetic anomaly, but it was not



Geological Society of America

Composite chart of the tracks in the South Atlantic made by various research vessels. The heavy lines are tracks of the German ship Meteor.

until 1954 that Bruce was pretty sure the association was real. In 1957, after twenty additional crossings, Ewing, Bruce, and a graduate student at Lamont presented a paper at the AGU meeting in Toronto, at which the discovery of the rift valley was announced. In their presentation they reported that the presence of a large positive magnetic anomaly (material at the top of the ridge that was more highly magnetized than the material on its sides) was associated with the rift valley as a general pattern.

'Bruce and I got our first real look at the rift valley in 1959 in movies taken by Cousteau . . . the great black cliffs . . . sprinkled with white glob ooze, loomed up through the blue-green water.'

Bruce and I got our first real look at the rift valley in 1959 at the First International Oceanographic Congress. The meeting was held in New York, and Bruce gave a number of papers. Jacques Cousteau was there too. He snagged us one day and showed us the tracks of his research vessel *Calypso* plotted on our physiographic diagram. He hadn't believed in the valley until he crossed it himself. So he took movies with his camera mounted on a sled, the *Troika*, which he showed to a large evening audience as an unscheduled event at the congress. On his film, the great black cliffs of the rift valley, sprinkled with white glob ooze, loomed up through the blue-green water. I think that Cousteau's movies may have convinced a few doubters at a critical time that our rift valley was really there.

In the following years, we continued to construct a detailed physiographic diagram of the rest of the Atlantic Ocean. The *Meteor* profiles were our main source of data, which we supplemented with such other data on the South Atlantic as were available. Our diagram of the South Atlantic Ocean, published in 1961, showed the Mid-Atlantic Ridge in the central third of the ocean. The prominent rift valley, at the crest, is strikingly parallel to the coasts of South America and Africa. Upon the publication of our diagram, one of our Lamont buddies came up to us and said, "Now you can hardly avoid the conclusion that you guys believe in continental drift." Of course, he was right.

Continental drift and plate tectonics are now accepted theories rather than heresies. The connection between the central rift valley and the movement of continents has become legitimate. And by the early 1970s, in a complete reversal, the disbelievers were the ones who were thought to have something wrong with them. □

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Nodes from the Underground

by Randy Moore

The Magaliesberg Range in South Africa's Transvaal Province is in highveld country. Plateaus up to 7,000 feet in elevation and prolonged winter droughts give the region its look of dusty rangeland. Like many rugged sites, Magaliesberg contains more life than first meets the eye. Camouflaged among quartzite pebbles that mottle parts of the highveld grows a model of adaptation known botanically as *Frithia pulchra.*

Slow-growing *Frithia*, like the New World cactuses, has struck a balance between the need to conserve water and the need to gather sunlight. Succulence—the development of thick, fleshy leaves with low surface-to-volume ratios—is just one way plants of arid regions hoard moisture while still intercepting light for photosynthesis,or food making. *Frithia*'s ten to fifteen plump leaves, each an inch or two

Both photographs by Anthony Bannister

Left: Frithia pulchra *grows among quartzite pebbles on South Africa's Magaliesberg Range. Above: Only the tops of the plant's fleshy leaves protrude above ground.*

Frithia's *translucent leaf tip*

Both photographs by Randy Moore

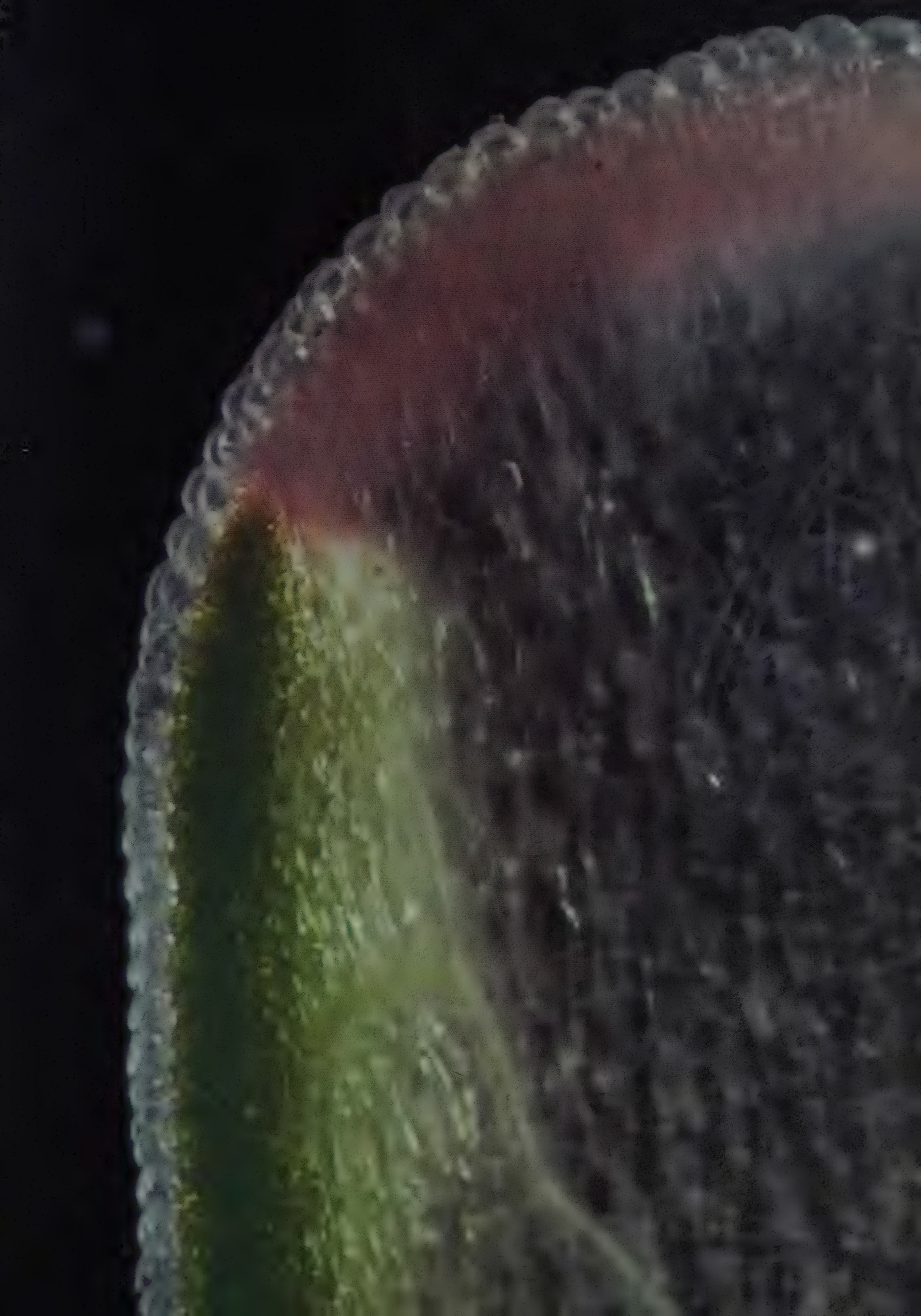
long, radiate from a central undergroun base. But *Frithia* has evolved a furthe distinction, rare even among succulents its leaf tips are translucent "windows" an are often the only parts of the plant visibl above soil level in its natural habitat. Th centrally located water-storage cells, als translucent, are wrapped in a cylinder o green photosynthetic tissue that is in tur bordered by the epidermis. Light comin through the windows can be intense. Th cells of the leaf tips, which filter and de flect entering light toward the chlorophyl reduce the level of radiation reaching pho tosynthetic tissue.

Frithia's stomata—minute pores o leaf surfaces that regulate gas exchang with the atmosphere—are not open dur ing the day, as they are in nonsucculents but open at night, when relative humidit is high and much less water is lost a vapor. Because the stomata are locate only on the sides of *Frithia*'s leaves, ga exchange takes place through the shallo gravel surrounding the plant.

Subterranean life lets *Frithia* flout th highveld elements. Exposure of only th leaf tips to strong light eases the plant' heat load, thereby sidestepping respira tory problems. Bright light penetratin the windows is deflected toward the sensi tive chlorophyll lining the leaves. Shel tered by pebbles, *Frithia* is at little risk o being dried out by the sun or wind, and it mimicry of quartzite protects it from th teeth of highveld grazers.

From the structure of its leaves to it cells, *Frithia* has evolved to meet th Magaliesberg challenge. In especially dr times, the leaves shrink completely int the earth and wait subsurface for bette days. After rain, they will swell an "throw open the windows." □

A longitudinal section of a Frithia *leaf reveals the translucent dome and central water-storage cells, cylinder of green chlorophyll, and bumpy epidermal outer border.*



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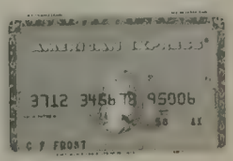

Needles and Spear-throwers

A wave of innovation at the end of the Old Stone Age made human groups the masters of space and time

by Robin Dennell

Early in this century, lacking modern dating techniques, archeologists divided up the paleolithic, or Old Stone Age, according to the types of tools unearthed at prehistoric sites. Perceiving a contrast between "assemblages" (sets of artifacts) of stone flakes and those of proportionately more elongated blades, they drew a major distinction between the middle paleolithic (100,000 to 35,000 years ago) and upper paleolithic (35,000 to 11,000 years ago). Other contrasts also pointed to a time of fundamental change. Besides efficiently making a large variety of tools from stone blades, upper paleolithic people made tools out of bone, ivory, and antler. They also seem to have been the first people to create art and to have buried their dead with grave goods. Their settlements were more densely distributed and often larger than those of the middle paleolithic, suggesting population growth. In addition, in Europe and the Near East, the remains of anatomically modern humans (*Homo sapiens sapiens*) are found only at upper paleolithic sites, whereas the middle paleolithic culture in these areas—known as the Mousterian—is always associated with Neanderthals (*H. s. neanderthalensis*).

While the contrast between the middle and upper paleolithic is widely accepted, experts still cannot agree about how the transition came about. Some insist that modern humans who used upper paleolithic tools migrated into Europe and displaced the Neanderthals. Others

On October 23, the American Museum of Natural History will unveil **Dark Caves, Bright Visions: Life in Ice Age Europe**, the largest exhibition of original upper paleolithic artifacts ever presented in the United States. The 300 objects selected for display include ancient sculptures, body ornaments, and tools made of stone, ivory, bone, and antler. The exhibition, prepared in collaboration with universities and museums throughout Europe and North America, will be on view in Gallery 3 through January 18, 1987.

Ibexes adorn the end of a spear-thrower carved from reindeer antler (actual length, about 3.6 inches). The hook at left was inserted into the end of the spear shaft; the handle, now missing, was to the right. The 13,000-year-old artifact was discovered at Enlène Cave, France.

Musée de l'Homme; J. Oster

A three-inch-long ivory horse, below, sculpted about 14,000 years ago, includes incised details of its coat and mane. It was found at the site of Lourdes, France. A 25,000- to 27,000-year-old "Venus" figurine from the French site of Lespugue, right, emphasizes features associated with fertility. Carved of mammoth ivory, it is nearly six inches tall.

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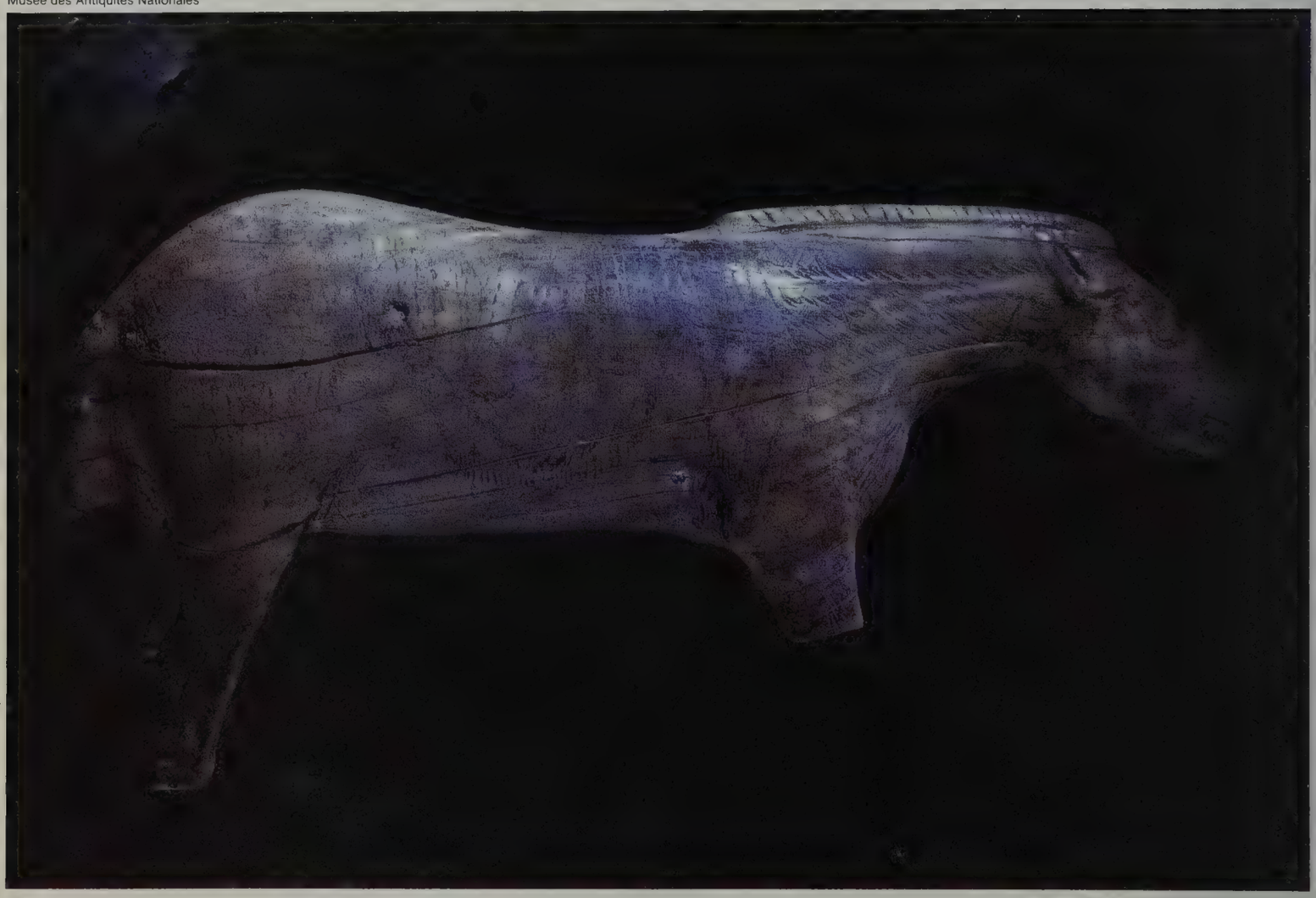


believe that Neanderthals evolved into modern humans and that the middle paleolithic gradually transformed into the upper. They point out that the earliest upper paleolithic assemblages of western Europe—known as the Châtelperronian—include the type of flake tools and stone-flaking techniques that were used before. Still other scholars assume some influx of new populations and techniques into Europe but allow the Neanderthals a more active role than that of witness to their own extinction. The French site of St. Césaire, where the remains of a Neanderthal were discovered in a 34,000-year-old layer containing a Châtelperronian assemblage, support this view. Not only may Neanderthals have been among the earliest users of upper paleolithic tools, but they may also have interbred with modern humans over a period of three or four thousand years.

In many ways, however, I feel that as a result of these debates, too much attention has been lavished on the transition between the middle and upper paleolithic and too little on events thereafter. Since all upper paleolithic stone-tool industries are based on blades, the substantial changes that occurred within that cultural period may have been obscured. A different picture emerges if the stone flakes and blades are set aside in favor of other lines of evidence.

The history of additional innovations is instructive. Cave sites in southwest France often preserve long sequences of deposits that can show when various types of artifacts made their first appearance. The interaction of technology and social organization with the environment is even more important, but this is admittedly difficult to study, since social systems cannot be dug up and put on display. One useful clue, however, lies in the environments that people could or could not cope with at different times of the upper paleolithic, especially during the rigors of Ice Age glaciation. Here, the Russian and eastern European sites are especially significant. Their existence shows, fairly unambiguously I think, that changes at least as profound as those about 35,000 years ago occurred again, perhaps 27,000 to 25,000 years ago.

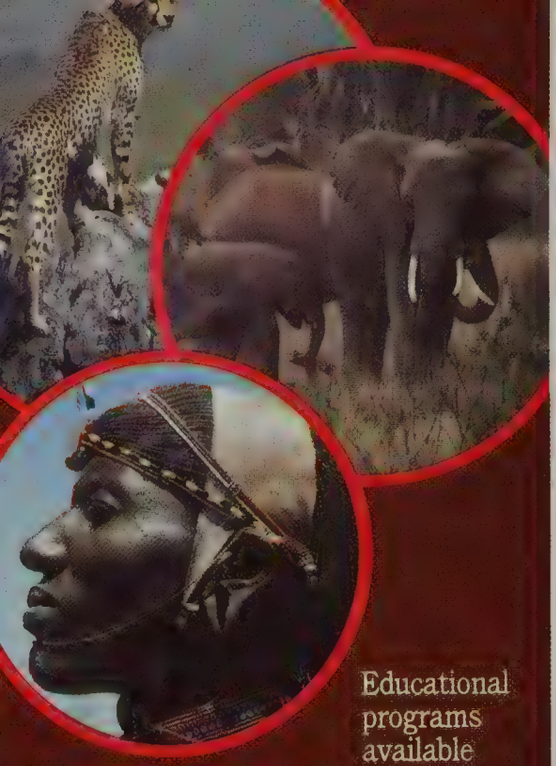
First of all, the earlier transition did not involve a clean break with the past. University of Tennessee anthropologist Fred Smith, among others, argues that some new populations entered Europe but that much of the change was local in origin. By and large, this view is consistent with archeological discoveries. Some of the earliest upper paleolithic assemblages in central and western Europe apparently derive from the preceding Mousterian, while oth-

Musée de l'Homme; J. Oster

ers appear intrusive. Innovations include the earliest bone points. If these were the tips of throwing spears, they may have made hunting easier and safer by replacing the Mousterian stone-tipped stabbing spear, which had to be used at close range. Beginning in the upper paleolithic, cobble-lined hearths enhanced cooking. And some crudely engraved slabs from La Ferrassie in southwest France and, perhaps, some animal figures from Vogelherd Cave in Germany provide the first glimpses of artistic representation.

Little else seems to have changed. At least in western Europe, people occupied the same caves in the early upper paleolithic as in the late Mousterian, and the population did not expand greatly. Hunters took the same animals as before, often in the same proportions. The few settlements in eastern Europe were also usually in the same areas as Mousterian ones. Overall, the picture is one of some change but shows substantial continuity as well.

The same cannot be said of the scale of changes that began about 27,000 years ago, by which time anatomically modern humans were well established. Several important technological innovations developed. One may have been the bow and arrow, judging by the 23,000-year-old concave-based stone points unearthed from Parpallo in Spain (many scholars, however, regard this tool as a later, mesolithic invention). More certain are the spear-thrower and harpoon, both inaugurated between 17,000 and 15,000 years ago, which increased the accuracy and efficiency of hunters. Traps, snares, and nets may also date from the later upper paleolithic. Some Russian sites, for example, contain the skeletal remains of fur-bearing animals, such as arctic foxes and hares, that lack only their paws—presumably detached with the pelt when the animal was skinned. These animals were probably trapped. Elsewhere, fish and bird remains are found in quantities that imply the use of nets. And cord was used at least 15,000 years ago: traces of it have been found at the cave of Lascaux in France (cord may have been used to lash wooden ladders that helped prehistoric artists reach the higher parts of the cave walls and ceiling).



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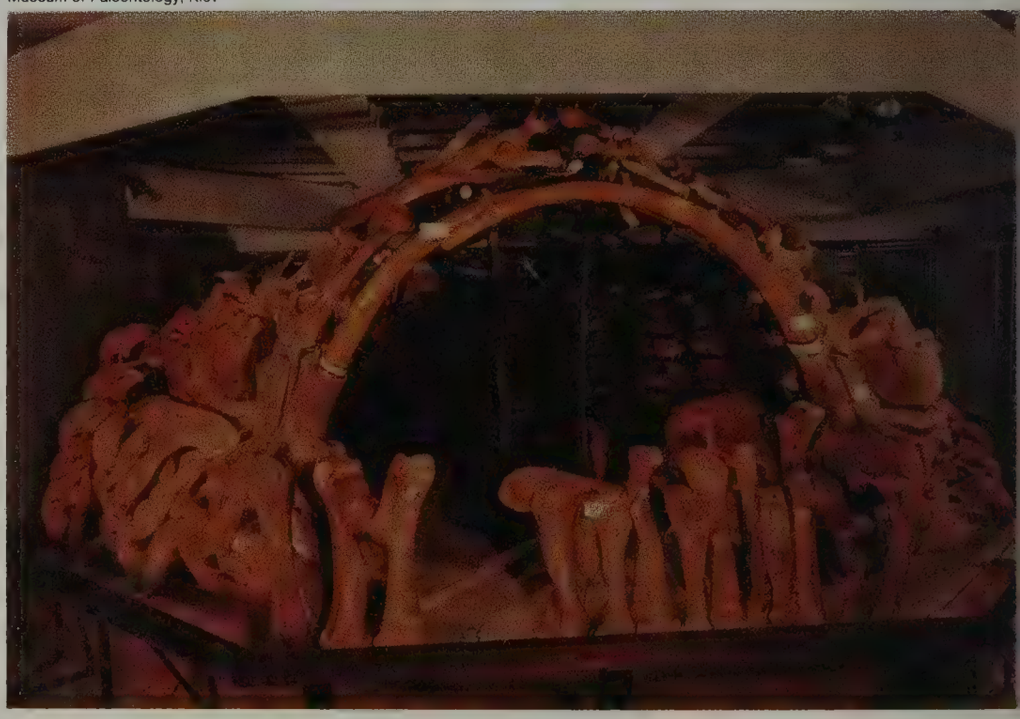
Selected archeological sites dating from 35,000 to 11,000 years ago are shown on the map below. Among them, Byzovaia, near the Arctic Circle, demonstrates that sometime after the beginning of this period, humans acquired both the technology and social organization needed to colonize previously uninhabited regions. A hut built of tons of mammoth bones about 16,000 years ago, bottom, was discovered at Mezhirich in the USSR. It was probably used for rituals or other special communal gatherings. Ivory needles 21,000 years old, right, come from the French site of Jouclas. With this invention early peoples could more easily tailor warm clothing for protection in harsh climates.

Joe LeMonnier

Museum of Paleontology, Kiev



Transportation also improved considerably after 27,000 years ago. Fur trapping probably required travel over snow, since pelts attain their prime condition in winter. In addition, some Russian sites, such as Mezhirich, contain structures built with up to twenty tons of mammoth skulls and long bones, which may weigh several hundred pounds each. I believe that a sledge was needed to transport all that material, most easily done in winter over compacted snow.

Advances in keeping warm were also made. The abundance of flint drill tips in the later upper paleolithic suggests that at least some were for fire drills, like those used by more recent hunter-gatherers. And the sewing needle made its debut some 23,000 years ago in southwest France—probably the most underrated

. White

nvention in the entire upper paleolithic perhaps because most prehistorians are nale and don't do their own sewing). Indiect evidence of tailored clothing exists rom the hints of trapping small animals or fur and in a 20,000-year-old grave rom Sungir, near Moscow, of an old man vhose body was clothed in a bead-covered unic.

Finally, although art first appears in the arly upper paleolithic, most dates from fter 27,000 years ago, and much of it rom some 10,000 years later. Within this liverse tradition, cave art has evoked adniration for its rendering of animals, often n a beautifully naturalistic manner. Some animals are merely drawn or engraved in outline, others have details of their hair and muscles hatched in or are painted in colors. Sometimes groups of animals are shown, such as the great friezes at Altamira in northern Spain and at Lascaux. In addition to the paintings, there are basreliefs of animals carved on slabs and clay sculptures, such as the pair of bison from Le Tuc d'Audoubert, another French site.

In Europe, most of the cave art is concentrated in southwest France and northern Spain, but some exists as far east as the Urals. Over this vast area, archeologists have also collected many pieces of portable art, generally known by the French term *art mobilier*. Some are utilitarian objects, such as spear-throwers, the ends of which might be worked into stunning, realistic animals. Other pieces are more enigmatic, such as the *bâtons de commandement*, which may or may not have been symbols of authority. There is

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A 13,000-year-old necklace from Rocher de la Peine, in France, includes dentalium shells obtained from the Atlantic coast and four large teeth from dangerous animals—three bear teeth and (second from right) a lion's tooth.

Logan Museum, Beloit College; R. White

also jewelry—mostly beads, bracelets, and pendants. These began to appear 30,000 years ago, but the finest examples come much later. Among them are the 2,000 ivory beads that adorned the tunic from Sungir. Making these demanded time and care: first, splinters of ivory had to be extracted, shaped into rods, and cut into segments; then each bead had to be drilled and polished before threading. Another example is a necklace from Rocher de la Peine, in France, which dates toward the end of the upper paleolithic. It incorporates seashells that came from one hundred miles away and the teeth of dangerous animals, such as bears and lions.

The best-known portable art objects, however, are the so-called Venus fig rines, which are dated between 27,00 and 25,000 years ago. These are sma highly stereotyped sculptures: typicall the breasts and buttocks are given mo attention, the face is anonymous (a though the hair is sometimes show plaited), and the figure is pregnant. Whi prehistoric artists usually portrayed an mals with fidelity, these human form were abstracted to be fertility images.

The uniformity of much of this art ov an area from the Pyrenees to the Urals (o put another way, over the same distanc as from New York to San Francisc shows there were social networks to di seminate and maintain both artistic styl

and beliefs over immense distances. This point leads directly to the second line of evidence that may be cited for the scale of change after 27,000 years ago: the broader range of environments that people could adapt to after this date.

During the early part of the upper paleolithic, people lived in the same areas as the Neanderthals before them. Their successors, however, regularly used regions that were previously uninhabited. This applies especially to the vast expanses of steppe and tundra in eastern Europe, which were frozen except for a short summer thaw. A striking example is the colonization of Siberia, which happened after 30,000, and probably after 27,000 years ago. A second is the site of Byzovaia, occupied briefly about 18,000 years ago, which is only one hundred miles south of the Arctic Circle (this site, incidentally, records the earliest known encounter between humans and polar bears).

The colonization of such areas as the Far North and Siberia, well beyond the range of Mousterian and early upper paleolithic settlement, and their continued use when climatic conditions deteriorated during the glacial maximum, about 18,000 years ago, required competence in making well-insulated clothing, moving efficiently over snow, trapping and killing animals, and lighting fires. But more than technological inventions were needed to cope with these harsh and fickle (though productive) environments. At least as important were the social arrangements that enabled bands of people to stay in contact with each other over large distances, to share information about the weather and the movement and availability of animals, and to exchange mates so that groups could survive as social units. In this, art may have played a key role: Margaret Conkey, of the State University of New York at Binghamton, and other scholars have argued that some of the main centers of upper paleolithic art may have been places where groups could convene periodically to pool information and reinforce social ties.

Long-range expeditions into harsh, unoccupied regions, far beyond places of habitual settlement, also generally date from

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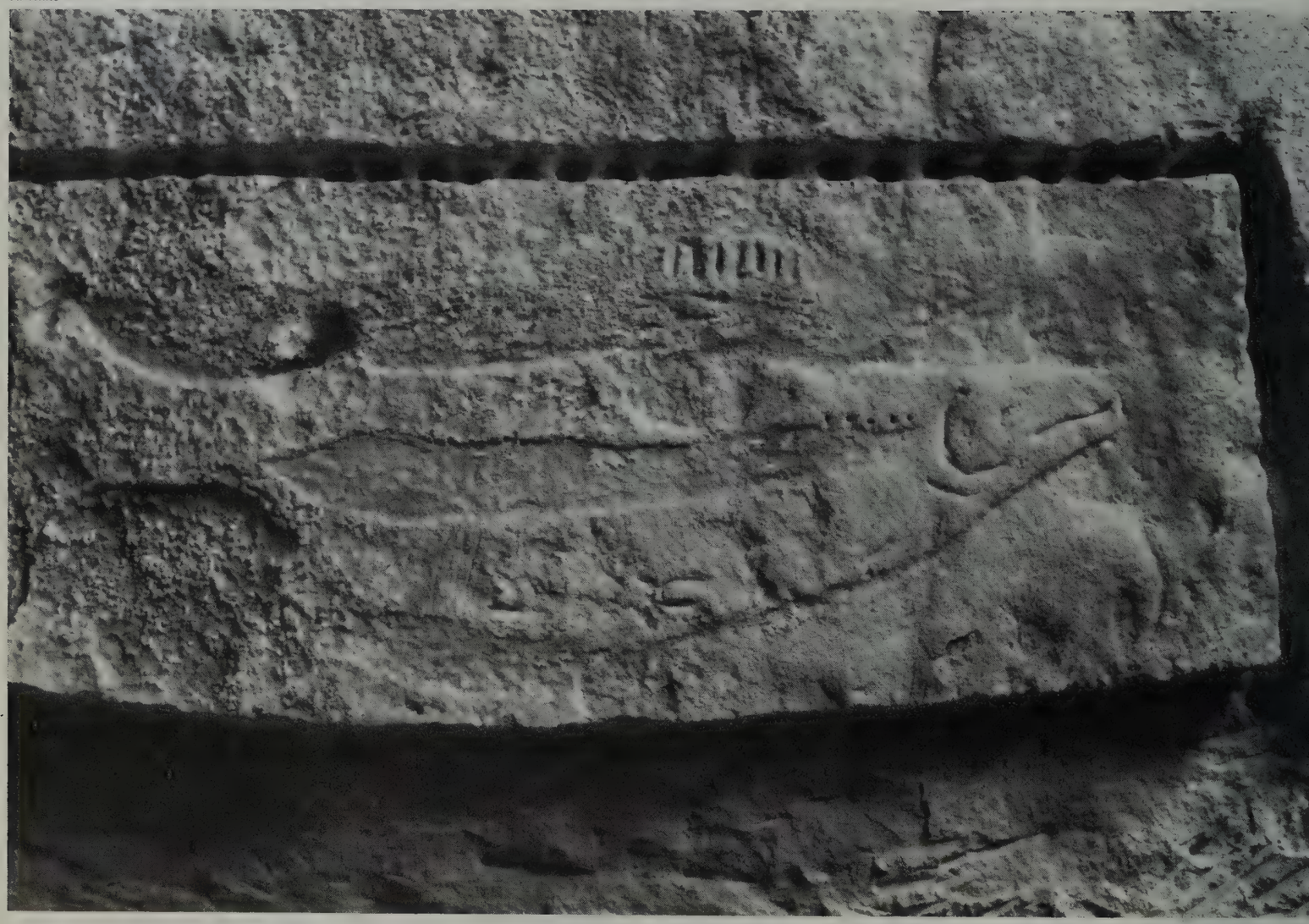
A salmon decorating the ceiling of Abri de Poisson, a rock-shelter in France, may be more than 27,000 years old. The cuts framing the fish date from early this century, when an attempt was made to remove the 42-inch engraving for sale.

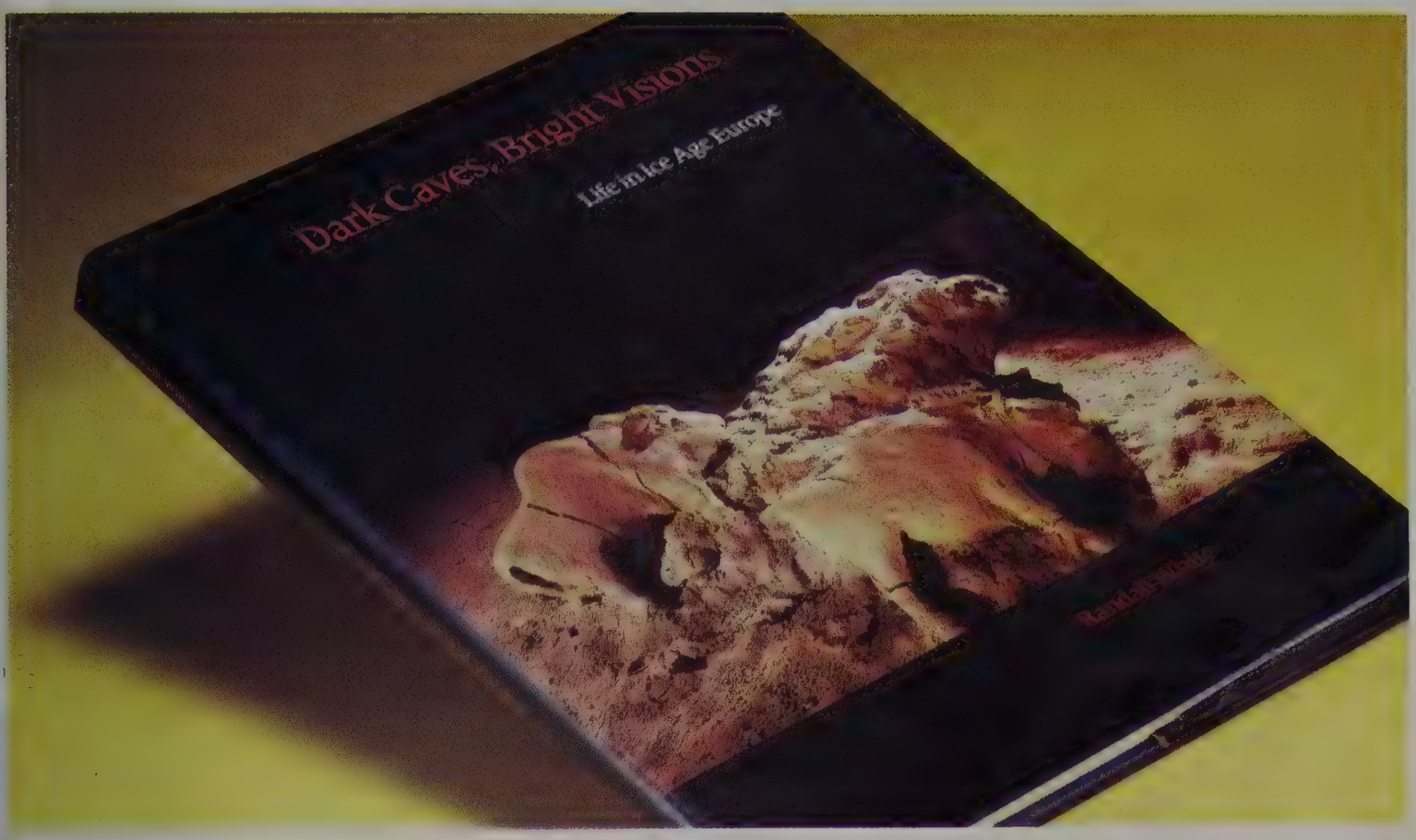
R. White



after 25,000 years ago. About 18,000 years ago, for example, when most of the British Isles were covered by ice sheets, the English Channel was dry land, and the nearest permanent settlements were in the Paris basin, a small group of people went north to where mammoths grazed near the edge of the ice sheet. Apparently they wanted to collect ivory. In any case, near Paviland, in southern Wales, one of them died, and his companions buried him with some ivory in an elaborate grave. A second example is Ossam's Cave, in northern England. Toward the end of the last glaciation, about 12,000 years ago, a small band of hunters trekked northward to this cave in late winter, in order to hunt reindeer and their newborn calves. This cave was probably the first available on a difficult 300-mile journey from what is now the coast of northern France.

Like the presence of Portuguese pottery along the coast of southern Africa in the thirteenth century A.D., these sites show the ability of modern peoples to navigate over long distances. There is no evidence that Neanderthals or people in the early upper paleolithic could make these kinds of journeys, far beyond familiar areas of year-round occupation. That they were undertaken, apparently on a routine basis, implies more than the availability of good footwear and portable field gear. Sites like Byzovaia, Paviland, Ossam's Cave, and others high up in the Alps suggest that in the later upper paleolithic, human groups could orient themselves over long distances to chosen destinations, anticipate the conditions they were likely to encounter, make appropriate arrangements, and (with exceptions like the young man buried at Paviland) return safely. Supporting evidence consists of such artifacts as a 16,000-year-old bone, found at Mezhirich in Russia, that seems to show a map of the area around the settlement; similarly, most of the artifacts interpreted as calendars date from after 25,000 years ago.

While the transition from the middle to upper paleolithic was important, the upper paleolithic itself witnessed more than occasional changes in styles of making tools and drawing animals. The emergence of fully modern behavior, illustrated by the way people operated in the steppe and tundra environments of eastern and northern Europe, constituted a second wave of innovation. An element of this revolution was the development of more effective technology, but the key was the ability to map space and time on a large scale and to maintain long-range social ties between scattered groups. □



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Tajique Canyon, New Mexico

by Robert H. Mohlenbrock

During the middle two weeks of October, an orange-red glow brightens Tajique Canyon, in the heart of New Mexico's Manzano Mountains. The color radiates from the leaves of the bigtooth sugar maple, a tree that ranges from Idaho and Wyoming south into Mexico but occupies only a few canyons in New Mexico. Local residents recall that many more maples once grew in Tajique Canyon, but a severe drought in the 1930s killed nearly half of the stand.

The Manzano Mountains are part of Cibola National Forest, whose parcels, totaling 1,700,000 acres, sprawl on all sides of Albuquerque. Also in Cibola is the state's tallest mountain, 11,398-foot-high Mount Taylor, which lies sixty miles west of Albuquerque, and Sandia Peak, which looms directly to the city's east. Both peaks are popular recreation areas, but the Manzano Range, twenty miles to the south, is little known to hikers.

Tajique Canyon lies between 9,509-foot Mosca Peak to the north and Capilla Peak, slightly lower, to the south. A dirt road leading west from Tajique, a village first settled in prehistoric times, meanders for seven miles up the canyon. Bigtooth maples become evident three-fourths of the way up the road but are most concentrated in the narrow end of the canyon, accessible only by a trail. Other trees—ponderosa pine, spruce, Rocky Mountain juniper, Gambel oak, and the pink-flowered New Mexico locust—add variety to the forest.

The sugar maples of the United States are an enigmatic group. The trees grow from Maine across to eastern Idaho and from Florida to western Colorado and western Arizona. They are also found in northern Mexico. All have a similar leaf shape, put forth small clusters of flowers after the leaves have expanded, and produce a sugary sap that can be tapped for maple syrup. Yet anyone who has inspected sugar maples throughout the country can see that the leaves of Vermont sugar maples don't look quite like the leaves of bigtooth sugar maples in Tajique Canyon or of southern sugar maples in the Florida panhandle or of those in Wisconsin or southern Illinois.

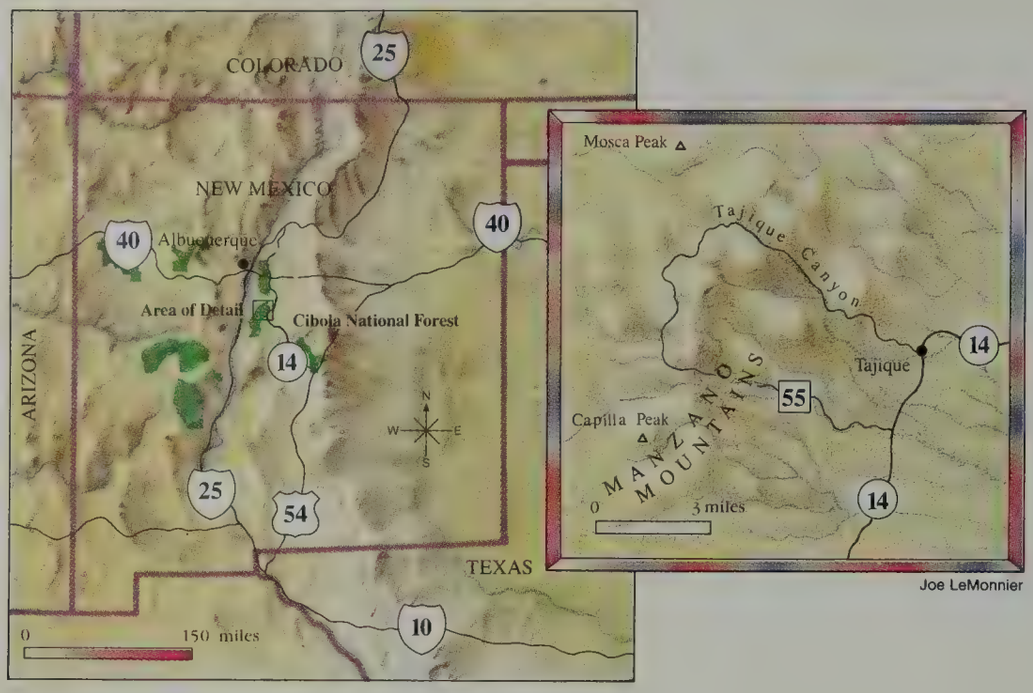
The leaf differences have led botanists to argue over whether the sugar maples of the United States all belong to one highly variable species or to several different but closely related species. Botanists generally prefer to distinguish between species of flowering plants on the basis of reproductive characteristics (flowers and fruits) rather than of leaf characteristics. Flowers and often fruits tend to be stable, showing little variation in response to environmental conditions. Leaves, on the other hand, may vary considerably depending on whether they are in the sun or the shade, whether they are on main branches or on sprouts, and sometimes whether they are on limbs that have flowers or limbs that don't have flowers.

Charles Sprague Sargent, the foremost student of American trees at the turn of the century, and a botanist who had little trouble distinguishing the great number of American oaks, found it impossible to draw lines of distinction between all the different forms of sugar maple in the United States. Consequently he called them all one species, *Acer saccharum,*

Lee Singer; U.S. Forest Service

Leaf shape is the only external character distinguishing the bigtooth sugar maple, opposite, from other sugar maples. Above: Tajique Canyon in autumn.

Russell Bamert



Joe LeMonnier

Tajique Canyon

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commenting that the sugar maple is the most variable of American tree species. Many botanists have agreed, pointing out that the flowers and winged fruits formed by all the sugar maples are virtually indistinguishable. Others, however, have felt that the differences in the leaves are too great to be ignored.

In recent years, new techniques have enabled scientists to analyze and distinguish plants chemically and genetically. As a result of new evidence, botanists are now leaning toward recognition of five closely related species: sugar maple (*Acer saccharum*) of the Northeast; black maple (*A. nigrum*) of the North; southern sugar maple (*A. floridanum*) and chalky maple (*A. leucoderme*), both of the Southeast; and the bigtooth sugar maple (*A. grandidentatum*) of the West. The genetic differences among these five species probably contribute to some of the leaf differences that have been observed, but other factors are also involved, including geographic location, climate, soil type, and underlying rock substrate.

Whether the trees in Tajique Canyon are bigtooth sugar maples or merely variations on a more general theme, they are a vivid sight during mid-October. The phenomenon of autumn leaf coloration is tied in with the aging and shedding of leaves.

In temperate regions where there is a cold season, most species of trees are deciduous. The shedding of leaves prevents damage caused by excessive drying. During the growing season, when water is usually plentiful, a tree takes in enough water to offset the loss of water from its leaves through transpiration. But in winter, water is often tied up in the form of ice. In addition, if living leaves were to remain on the tree during winter, the leaf cells would be damaged or destroyed by the constant freezing and thawing of water within them. (In coniferous trees, whose slender needles are adapted to wintry weather, and in most tropical trees, leaves do not fall annually during a particular season.)

The green color of most spring and summer leaves is due to the presence of great quantities of chlorophyll, the chemical compound that plays a major role in photosynthesis. Small quantities of other pigments—orange and yellow carotenes and pale yellow and brown xanthophylls—are also present in certain leaves but are masked by chlorophyll.

Pamela Bamert

In autumn, the breakdown of chlorophyll unmasks other leaf pigments.

All through the spring and summer most of the leaf cells manufacture sugars. Some sugars are used immediately for needed energy, while others are transported to other parts of the plant and stored in the form of starch and other compounds. Still other sugars accumulate in the leaves, where they eventually cause a breakdown of the chlorophyll. As the green pigment disappears, the oranges, yellows, and browns of the carotenes and xanthophylls become apparent. The accumulation of sugars in some leaf cells may also result in the production of bluish and reddish pigments, called betacyanins and anthocyanins.

Some trees, such as aspens, which turn light yellow, display a uniform color because of the dominance of a single pigment. The leaves of ashes often turn a deep maroon, sumacs radiate with red. Sweet gums, instead, offer a variety of colors, even on the same tree. Other trees, including the orange sugar maples, vary considerably in color from place to place or from tree to tree.

As the leaves age further, any remaining sugars are conducted to various food storage organs of the plant, such as the roots. The leaves are then shed through a process called abscission. When a maple leaf is young, hormones inhibit this process. But after the heat of summer, hormonal changes give rise to new regions of leaf cells. Several layers of cells at the base of each leaf stalk become filled with a fatty substance known as suberin, the same substance that gives cork cells their spongy texture. Just above these "suberized" cells, a "separation layer" forms as other cells swell with a gelatinous material. At the end of summer, as the cement that holds plant cells together breaks down, these enlarged cells become especially liable to separate. Eventually wind and rain knock the leaf off the plant where the separation layer has developed. The exposed corky cells now serve as a kind of scar tissue, protecting the tree from water loss and the introduction of disease during the long winter months.

"This Land" highlights the biological phenomena of the 153 U.S. national forests. Robert H. Mohlenbrock is distinguished professor of botany at Southern Illinois University at Carbondale.

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A Life Among the Chimpanzees

by Alison Jolly

Jane Goodall is one of the wise people in the field of primatology. There are few wise people in any field; they are precious. Goodall has preserved her own vision in the face of journalistic pressure to make her chimpanzees seem lurid or sentimental and in the face of equally pernicious academic pressure to make chimps duller than they really are. If she has managed to keep her balance for twenty-five years, perhaps we should not be surprised that from the start, she could hold her ground against charging, shrieking chimpanzees.

The Chimpanzees of Gombe: Patterns of Behavior sums up two and a half decades of research. Filled with tables and diagrams and reasoned conclusions, it is not written as a popular book but should become a best-seller all the same, and not only because of the pictures on nearly every page. Goodall's fascination with the chimpanzees as individuals, and her conviction that scientific study of chimp behavior should illuminate the role of indi-

Chimpanzees rest and groom one another H. van Lawick

viduals in society, make *The Chimpanzees of Gombe* a delight to read.

In 1959, Louis Leakey sent his protégé to study chimpanzees on the shores of Lake Tanganyika. She worked mainly alone, though her mother joined her for the first few months, as the authorities would not let a single white girl stay there by herself. Graduate and undergraduate students started arriving in 1964. Camp grew to become the Gombe Stream Research Center and many colleagues' papers and theses are cited in this book. Then in 1975, guerrillas from Zaire kidnapped four students. Although the students were returned unharmed, most foreigners were no longer permitted to stay in the park. The Tanzanian staff continued to make observations, however, and

THE CHIMPANZEES OF GOMBE: PATTERNS OF BEHAVIOR, by Jane Goodall. *The Belknap Press of Harvard University Press, $30.00; 655 pp., illus.*

Goodall helped them take over the task of collecting data. Now Goodall spends three weeks in the park at intervals of two months or so, consulting with her twelve skilled field assistants, who follow known chimps on a daily basis and are habituating new groups to the north and south. More information than ever is coming from the Gombe Stream.

Fashions and preoccupations in primatology have changed over the decades. It may be interesting to recall how some themes of Goodall's work originally struck the rest of us and how our attitudes have grown. The theme of the individual's importance started early. Goodall named her chimps as soon as she could recognize them. At that point only the Japanese admitted to being sensitive to individual primate temperament, and they admitted it to each other in Japanese. Western primatologists wrote instead of *the* adult male, *the* adult female, or *the* juvenile. Most of us still thought that field studies of a year

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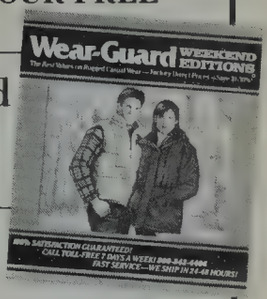

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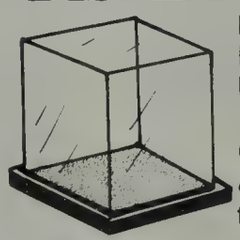

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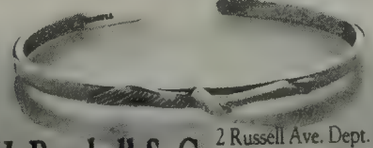

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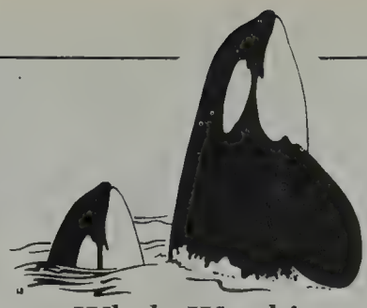

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would suffice to decipher social structure We had no conception of how much troop and populations would differ within a spe cies or of the importance of historical an demographic changes, let alone about th effect of individuals on their comrades. I the early 1960s, traditionally traine ethologists wondered how seriously to tak Goodall, even when she promised to com in from the wild and write a doctorate a Cambridge.

Now Goodall's approach has been full justified. No one doubts, for instance, tha the successive alpha, or dominant, male of the Gombe have used different tactic and have differentially affected their com munity. Clever, determined Mike won hi position in 1964 by banging empty kero sene cans. Goodall writes:

> Mike's deliberate planning was a strikin aspect of his rise . . . . Once, a group of si adult males [all higher ranking than him self], groomed about 10 meters away Mike, after watching them for six minutes got up and moved toward my tent. His hai was sleek and he showed no signs of an visible tension. He picked up two empt cans and, carrying them by their handles one in each hand, walked (upright) back t his previous place . . . . After a momen Mike began to rock almost imperceptibl . . . . The other males continued to ignor him . . . . Mike rocked more vigorously, hi hair became fully erect, and uttering pan hoots he suddenly charged directly toward his superiors, hitting the cans ahead of him The other males fled . . . [then] returned and with submissive gestures began t groom Mike.
>
> [Mike became a] benign alpha, . . . ex ceptionally generous in sharing meat, . . . a zealous groomer . . . [even] of subordi nates.

Mike's successor, big, brutal Hum phrey, was the alpha from 1970 to 1972 He attacked not only males but also fe males, ripping open their estrous swell ings, perhaps in part enraged by a recur rently infected ear. Then Figan, backed up by his partly paralyzed brother Faben fought and defeated Humphrey, launch ing a surprise attack on the big male in his night nest. Although willing to fight Figan was exceptionally socially adroit He maintained his power for ten years by manipulating or forming alliances with other chimpanzees, including the deposed Humphrey. One final alliance, however undid him: young Goblin attached him self to Figan and was frequently defended by the older male, although Goblin him self never helped his protector. Goblin turned on Figan in 1979, but there was a long period of instability before Goblin finally qualified as the undisputed alpha in 1984.

Male chimpanzees do not recognize or have special interactions with their infants. A young male with an older brother or uncle follows and copies his "hero"; one who has no such role model must timidly follow groups of adults or find a special protector, as Goblin found Figan. Young females, however, have their mothers as lifelong friends. A mother frequently travels with an adult daughter, even when one or both are in estrus. In the Gombe, the interval between births if an infant lives is a full five years. Females lead a very special life in a period of estrus; they may be surrounded by parties of eager males (Flo managed fifty copulations with fourteen different males in one day), or they may go on courtship "safaris," traveling alone for days or weeks with a single mate. In the four and a half years a female is out of estrus she sometimes joins larger parties, but much of the time she feeds alone with her children or with her mother and her mother's children.

Again, individual differences are marked. Old Flo was a warm, protective mother, popular not only with males but also with other females. She tolerated her adolescent son, Flint, to the point where he rode on her aged back long after the normal time. Flint eventually sickened and died three weeks after his mother's death. Flo's daughter Fifi takes after her—she is sexually popular and a very capable mother. At the other extreme, Passion, the infant-killer, and her daughter Pom were both nervous and tense with courting males. Females, not surprisingly, avoided them, since Passion and Pom cooperated to seize and eat baby chimpanzees.

In Goodall's early monograph on chimpanzee behavior (1968), and in *In The Shadow of Man*, she described the warmth and care of chimpanzee motherhood. At the time this was a welcome antidote to the raw aggression Robert Ardrey and Konrad Lorenz pictured among our prehuman ancestors. The same theme continues, but she now tells of the children and grandchildren of the 1960 mothers. Her chapters on friendly relations and grooming emphasize the closeness of chimpanzee bonds and the variety of ways chimps have to greet, reconcile, and distract each other. However, Goodall writes:

> Had my colleagues and I stopped after a mere ten years, . . . we would have been left with the impression that chimpanzees were far more peaceable than human beings. Because we were able to continue beyond the first decade we could document the division of a social group and observe the violent aggression that broke out between the newly separated factions. We discovered that in certain circumstances chimpanzees may kill and even cannibalize . . . their own kind.

She describes the birth and death of the new community. She gives us the grisly details of attacks by gangs of males on animals who were formerly members of their own group. Goodall asks, "Do chimpanzees show intent to kill? and are they on the threshold of warfare?" To both questions she answers, yes.

In contrast to their initial puzzlement and present admiration for Goodall's work on social behavior, scientists immediately recognized the importance of her observations of tool making. At her first conference in 1962 at the Zoological Society of London, Goodall showed up with pictures of Gombe chimpanzees stripping twigs and grass stems, biting off bent ends, and using these fashioned tools to fish for termites. Louis Leakey, her mentor, pointed out that we could abandon the then current definition of man, as the "toolmaker," or change the definition of tools . . . or else just decide that chimpanzees are human.

As usual, when apes do something that

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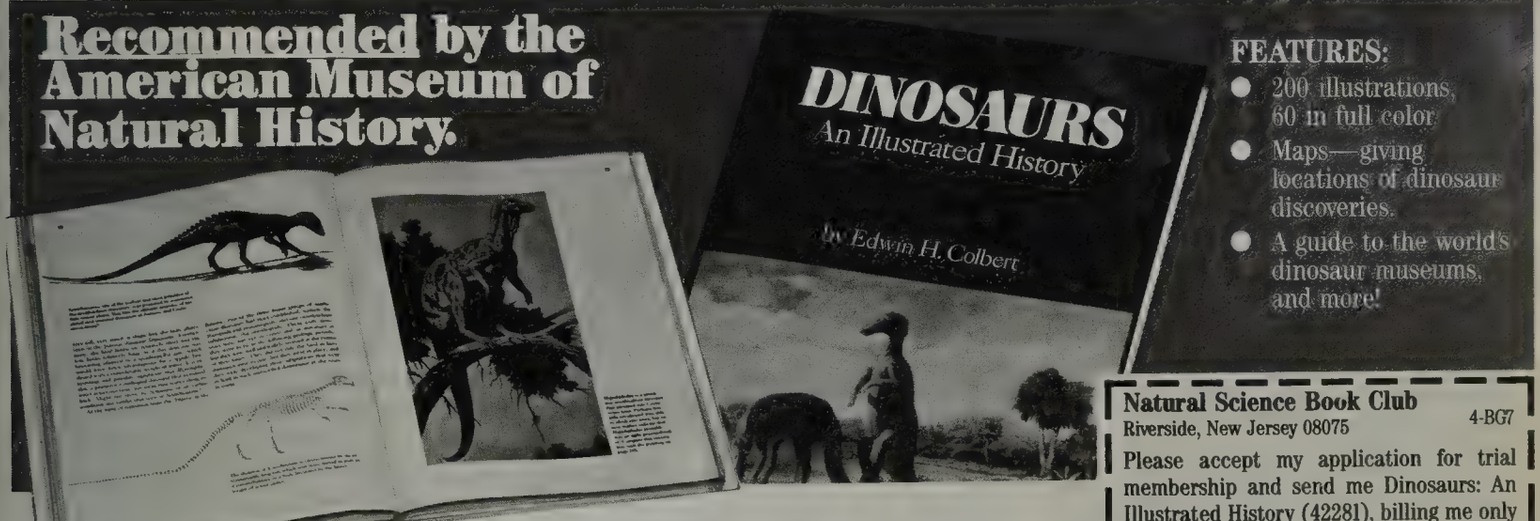

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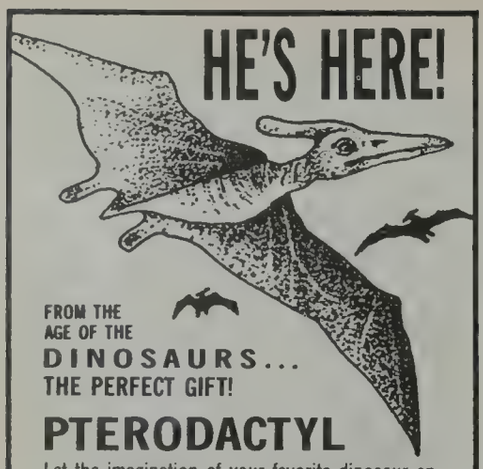

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before seemed wholly human, we fuss for a while, and then decide that this accomplishment is not really so decisive (the language-trained apes face the same mental block). In her new book Goodall recounts what to me are much more interesting, later discoveries about tool use. Termiting, and other complicated manipulations, such as nest building, are learned over at least three years of play. Infants observe their mothers and siblings and copy them, only gradually gaining proficiency. Tool use, like everything else, differs according to sex: females may squat for hours by a termite mound patiently dipping in all seasons; males hardly fish for termites at all, except at the height of the productive months, in November, when winged reproductive termites are ready to fly. Do females need a more regular protein source, especially since males hunt and eat meat more often? Do females have more patience? Do the males attack the "new" food with such gusto in November that they fish longer and eat more even than females? Or are they fishing longer because they are inefficient? Not only sexes but populations differ in their tool-using techniques. In both east and west Africa some chimps fish like those at Gombe, but in Rio Muni, chimpanzees use larger sticks to perforate the sides of termite nests, rather than dipping in the termites' own tunnels. These are cultural traditions, as are the variety of different tools for other foods: like long wands to catch biting ants or chewed-leaf sponges to soak up water.

Individuals again have individual styles, as Goodall demonstrates:

> Two young females, Pom and Gremlin, are acknowledged by all of us at Gombe as the current champion termite fishers. Both tend to select very long tools. Gremlin had one dry season tool that measured just over 1.5 meters, of which she inserted more than two thirds into the passage she was working. This required considerable skill, including a dexterous rotation of the wrist. When I tried to use her tool after she had left, I only managed to get half of it into the passage.

Pom's mother, Passion, had the same problem. She repeatedly supplanted her daughter at a difficult tunnel; whenever Passion gave up empty-handed Pom took over again with renewed success.

How intelligent are chimpanzees? How much are they aware of the consequences of their actions? These questions have been implicit in much of Goodall's earlier writing, but they form the backbone of *The Chimpanzees of Gombe*. The book opens with "The Mind of the Chimpanzee," a chapter that reviews laboratory work from Sultan, who was joining sticks

1917, to the language-trained Washoe, who is now teaching linguistic hand signs to her adopted son. The concluding chapters discuss social awareness; within the fluid society of the chimpanzee, the animal needs to calculate what allies it has in earshot and how and when to be confident or subordinate in a given group. Chimpanzees manipulate others, seek and give aid, and even lie. They can suppress calls and facial expressions, as adolescent Figan learned, so as not to give away the presence of bananas to the adult males. They may even actively deceive, as when Figan strode into the woods, leading the other males away, then doubled back to reclaim his bananas in peace. Goodall points out that he almost certainly was headed for a known food source: "The chimpanzees have far too sophisticated a knowledge of ripe food to follow a youngster in an unprofitable direction. Figan's 'lie' was to travel in the direction opposite of *his* food goal."

The years of careful scrutiny, quantified whenever it helps, told as single observations when that is more revealing, give us a picture of the mind of Gombe chimpanzees. We no longer need ask: why have they evolved to be so clever? Cleverness helps them deal with their patchy, demanding environment and the highly complex demands of chimp society.

We are left with a more disturbing question. What are our responsibilities to creatures capable of foresight and feeling? The Gombe Reserve is now islanded by agriculture. Only 150 chimpanzees can live there. Is this enough to escape the hazards of inbreeding or the ravages of random drought and disease? What about the other African apes in a continent whose human populations are in crisis, succumbing to famine, debt, and war? And what do we owe those ambassadors for their species who live in the zoos and laboratories of our own rich land? Goodall is now sponsoring ChimpanZoo, a project that gathers data on the social life of several groups of zoo chimps—and incidentally leads the zoos to enrich and appreciate their social lives. But they are like humans half in prison, half in a spaceship colonizing a forever alien world. To understand the ancestral home and lives of apes—and human ancestors—we must look back to Africa, and first and foremost to the chimpanzees of Gombe.

Alison Jolly is a guest investigator at The Rockefeller University. She has worked on lemur behavior and conservation in Madagascar and has written a text, The Evolution of Primate Behavior *(MacMillan and Co., 1985).*

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At the American Museum

Planetarium Concert

Environmentalist-musician Paul Winter will bring his blend of jazz, choral arrangements, and African and Brazillian rhythms to the Planetarium for two concerts on Wednesday, October 15. As Winter and his band play, stars, planets, moonscapes, and lasers will appear on the dome of the Sky Theater. The sounds of whales, loons, wolves, and other animals are featured in many of the band's pieces. Performances will take place at 6:30 and 9:00 P.M. Tickets are $16 for members and $20 for nonmembers. For more information call (212) 873-1327.

Ice Age Man

Evidence discovered in prehistoric caves and open-air sites indicates that by the late Ice Age, humans had developed art forms, complex symbolic rituals, and systems of regional exchange that were to be the foundations of modern culture. *Dark Caves, Bright Visions*, the sequel to the Museum's 1984 exhibition *Ancestors: Four Million Years of Humanity*, will bring together the largest collection of original paleolithic artifacts ever shown in one place. This exhibition, which opens Thursday, October 23, in Gallery 3, will feature more than 300 original etchings, sculptures, and tools from European and North American collections, as well as replicas of painted cave walls.

Spiritual Healing

The Venezuelan cult of Maria Lionza is a relatively new belief system. It originally centered on the worship of Maria Lionza, an Amerindian mother figure who grants favors and healing for devotees. Today, this worship is undergoing changes, incorporating influences from eastern Asia and Afro-Cuban Santería. On Friday, October 10, at 7:00 P.M., Dr. Angelina Pollack-Eltz, professor of anthropology at the Universidad Catolica Adesso Bella in Caracas, will present a free slide lecture illustrating the religious rituals of Lionza cultists, including the worship of "The Seven African Powers."

Supernatural Tales

Storyteller Laura Simms will give three shows in this year's Halloween program, *Spirit Stories From Around the World*. On Friday, October 31, at 7:30 P.M., Simms's stories for an adult audience will include one about a girl who married a ghost and an Inuit legend of a woman who possessed the knowledge of fear and death. The mystery of Big Toe and Simms's recipe for becoming a witch are part of a children's program on Saturday, November 1, at 1:30 and 3:30 P.M. All three shows will take place in the Kaufmann Theater. Tickets for each are $3 for members and $5 for nonmembers. For more information call (212) 873-1327.

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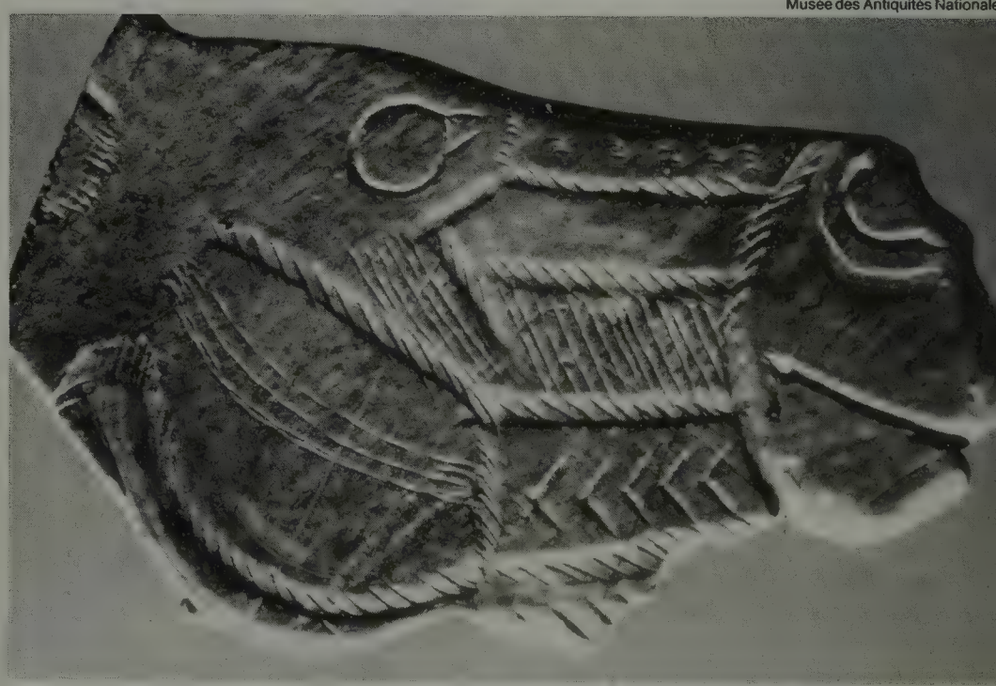

Upper paleolithic engraving of a horse's head, carved into a flat piece of bone

Culture and Violence

Violence will be the subject of a three-part program entitled *Culture and Violence*, to be presented by the Education Department in conjunction with the Post-Graduate Center for Mental Health of the City University of New York. The three sessions will explore the history of violence in society, domestic violence, and violence as it relates to the media. This free program will take place on October 1, 15, and 26. For more information call (212) 873-1300, ext. 514.

Africa Month

October will be *Africa Month* at the Leonhardt People Center. Performances, demonstrations, and films illustrating the many traditions of African culture will take place each weekend. These free programs will be repeated from 1:00 to 4:30 P.M., and seating is on a first-come, first-served basis.

Messenger

Joyce Cutler-Shaw conceives of the artist as a messenger of hidden events, current events, and survival. The central image of her work is the carrier pigeon. On Friday, October 24, at 8:00 P.M., Shaw will present her multimedia show in the Kaufmann Theater. As Shaw reads from her work, images of pigeons and other birds are projected onto a screen. Tickets for this program are $4 for members and $6 for nonmembers. For more information call (212) 873-1498.

Lecture Series

The museum begins its fall lecture series on Tuesday, October 14. This year's program will survey some twenty different topics. Among the subjects will be a three-lecture series on the Hittites of Asia Minor, and a four-lecture series on whales of the Atlantic Ocean. The latter will include lectures by Dr. Charles Mayo, director of research at the Center for Coastal Studies in Massachusetts, and by David Matilla, director of humpback whale research at the center. Randall White, guest curator of *Dark Caves, Bright Visions*, will present a three-lecture series on life in Ice Age Europe, which will include a private viewing of the exhibition. Other topics range from the culture of Morocco to insects. For a brochure that includes details and registration information call (212) 873-7507.

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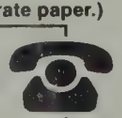

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A Good Month for Planets

by Thomas D. Nicholson

The planets are all evening stars throughout October, but that won't last long once the month ends. Venus leaves the evening sky in early November; Mercury and Pluto by the middle of November. But for all of October, Mercury and Venus are in the west, setting shortly after the sun; Saturn is low in the southwest; Mars is almost directly south, and Jupiter is rising in the east at sundown.

Venus is at its greatest brilliancy when October begins. At this stage in its configurations, however, the planet is closing rapidly with the sun. Besides, whenever it is an evening star in the fall, as it is now, Venus is always quite low for Northern Hemisphere viewers. Because of those conditions, it will be difficult to observe this month.

Saturn, Mars, and Jupiter are spaced about equally apart from the southwest toward the east at nightfall and follow one another westward in the above order through the night. Saturn, in Scorpius during the first half of the month, is just above the constellation's bright star Antares and sets before midnight. Mars and Jupiter are among the dim stars of Capricornus and Aquarius, respectively, which accentuates their great brilliance.

October brings the first eclipse of the year to North America, a fairly good partial eclipse of the sun (total and annular elsewhere) during the new moon of the 3rd. But the total lunar eclipse of the 17th is timed badly for us. It will be seen mostly in the Eastern Hemisphere.

Events in the calendar below are given in local time unless otherwise indicated.

October 1: The old crescent moon dominates the morning sky; the planets dominate the evening on this first day of the month. The slender moon, rising low in the east during early twilight, is only two days before new. Greatest brilliancy in the evening sky for Venus is, ironically, also a signal that the planet's sojourn as an evening star is close to ending.

October 3: The moon is new at 1:5 P.M., EST, and a solar eclipse occurs ov most of North America, the adjace North Atlantic, the Caribbean, and nort ern South America. A brief total eclip (momentarily annular at the beginnir and end) takes place along a short, narro path between Greenland and Iceland. Th eclipse is partial elsewhere, including a of North America except the West Coas where the event takes place before the su rises. The circumstances of the eclip (time, duration, and extent of the sun co ered) vary with location. It occurs short after noon along the East Coast and pr gressively earlier to the west.

October 4–6: Mercury is improving i position in the evening sky, and on th night of the 5th the crescent moon ma help in locating it. Try looking with bino ulars below and to the right of the moon late twilight. An occultation of the plan occurs in the Eastern Hemisphere whe the moon moves in front of it early on th 5th. The crescent moon joins Venus in th evening on the 5th and 6th, closer to th planet on the 5th; to its left and above it o the 6th.

October 7: The moon is at perige (nearest the earth) in the morning, an passes Saturn and Antares, in Scorpiu during the afternoon and evening. Satur (above) and Antares (close by and belov will bracket the crescent after sundow Viewers in western North America an much of Central and South America ca see the moon cover Antares (an occult tion) at about 6:00 P.M., EST.

October 8–10: The waxing moon move through Sagittarius on these evenings. I position on the 9th is almost exactly in th center of the "teapot" of stars that mo easily marks the Archer.

October 10–11: First-quarter moon on the 10th at 8:28 A.M., EST. As it slide toward Capricornus on the evening of th 10th, the moon is catching up with Mar but they set before the moon passes th planet. When they appear on the evenin

Celestial Events

f the 11th, the moon is past the planet, to s left and moving away. Although Mars s only a quarter as bright as it was at its uly peak, it is still easily seen.

October 12–13: The moon moves out of Capricornus on the 12th, into Aquarius on he 13th. It is moving away from Mars (to ts right) and toward Jupiter (to its left). The two bright planets are easy references rom which to follow the moon's easterly novement from night to night.

October 15: Venus begins its retrograde westerly) motion among the stars, taking t even more quickly out of the evening ky. When it becomes dark enough to see he stars tonight, the bright gibbous moon s just a little south of the vernal equinox. Note the position of the moon relative to he stars just above it in the Square of Pegasus, and you will have a reference to he "First Point of Aries."

October 17: Full moon, in Pisces, is at 2:22 P.M., EST. It will also pass into the earth's shadow, causing the second eclipse of the month, and the fourth and last of the year—a total lunar eclipse. But since it will be midday in North America when the moon is full, the eclipse will be seen mostly in Europe, Asia, and Africa. Tonight's moon is the hunter's moon.

October 18: Mercury is in conjunction with Venus in the evening sky, but they are so low during twilight and set so early that it may be difficult to find them. If you can see the much brighter Venus, search with binoculars for Mercury.

October 20–21: The bright waning moon rises in Taurus before midnight on both nights. Look below the moon for the reddish Aldebaran in the V-shaped group that outlines the Bull's face. There is probably too much moonlight to see the Pleiades (the Seven Sisters) to the moon's west. Mercury is at greatest evening elongation on the 21st but may be difficult to locate.

October 23: Apogee moon (farthest from the earth) is in Gemini.

October 24: The moon is in eastern Gemini, near Cancer, when it rises tonight

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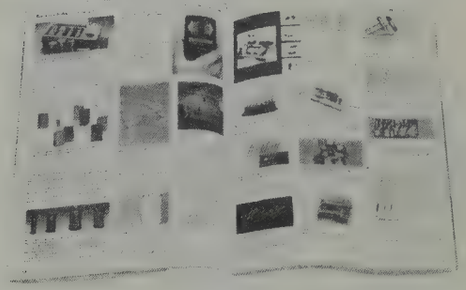

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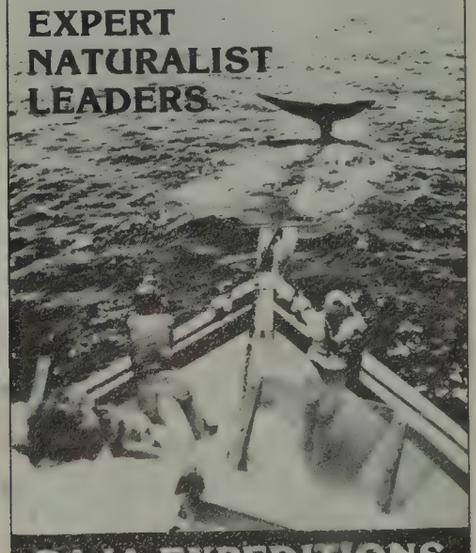

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at about 9:00 P.M. Gemini's two bright stars, Pollux and Castor, are in line with and above the moon, making the "twins" virtually into a threesome.

October 25: Last-quarter moon is at 5:26 P.M., EST, in Cancer.

October 27–28: Regulus, in Leo, is the star below the moon when they rise tonight after midnight. They are well up in the east by dawn on the 28th.

October 29–31: Virgo is home to the waxing crescent moon in the morning sky, rising before the sun and remaining up through twilight and into daytime. The bright star nearby on the 31st is Spica visible low in the east for a short whi before daybreak.

The fall Sky Map shows constellation and stars for October, November, and D cember from latitude 40° north at th hours given below. To use the map, hold vertically in front of you with south (S) the bottom and match the lower half the map with the stars you see when yo face south. As you face other direction roll the map to bring the correspondin compass direction to the bottom of th

ap. The stars move west continuously uring the night. By morning (before awn), stars on the western half of the ap will have set, those on the eastern alf will have moved into the west, and ew stars (those of the spring evenings) ill have risen in the east. The map shows he sky at about 2:00 A.M. on October 1; 00 A.M. on October 15; midnight on Oc- ober 31; 11:00 P.M. on November 15; 0:00 P.M. on November 30; 9:00 P.M. on ecember 15; and 8:00 P.M. on December 1. The map can be used for an hour or ore before and after the times given.

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Here We Go Round the Mulberry Bush

Spread a sheet beneath the tree to collect fruit for pies, jam, or eating out of hand

by Raymond Sokolov

When he beheld his shadow in the brook,
The fishes spread on it their golden gills
When he was by, the birds such pleasure took
That some would sing, some other in their bills
Would bring him mulberries . . .
—Shakespeare, *Venus and Adonis*

Lacking the physiognomic dazzle of Adonis, I have never been brought mulberries by any bird, or even any person. And until last summer, I had never knowingly seen, not to mention tasted, the fruit of *Morus nigra* or *alba* or *rubra*. Had you asked me about it, I wouldn't have been sure the mulberry was edible. For me, it was just one of those old-time fruits, like the medlar or the bullace, that crop up in English literature but not in American markets.

Enter Nicholas King, savant Manhattanite, keen urban observer, who led me, folding kitchen ladder in hand, to two fruiting white mulberry trees behind a lo fence next to P.S. 6 at the very edge Madison Avenue. King bent the branch down; I plundered the soft, pale whi berries. This was a sight that jarred ev jaded East Siders: two men, one of the distinguished looking (King), picki strange fruit.

"Are they some kind of raspberry?" woman inquired. It was a good questio The mulberry looks a bit like a raspber But the raspberry (along with the oth brambles, members of the genus *Rubu* such as the blackberry) is an aggrega fruit generated by a single, if comple flower. The mulberry is a so-called colle tive fruit, the product of many flowe originally attached to a single catkin. T fig, another example of a collective fru is a member of the mulberry family, t Moraceae, as is the banyan, the brea fruit, the hop, and the osage orange.

We botanical sophisticates can easi

Mulberries

Leonard Lee Rue III; Bruce Coleman, I

A Matter of Taste

ee how taxonomists linked these plants, ut pre-Linnaean folk looked at black nulberries and blackberries and saw nostly similarities. This is why the com-non French word for mulberry, *mûre*, vhich is descended from the Latin *morus*, s also the French word for blackberry. Vhen they want to distinguish the two ruits, the French call blackberries *mûres auvages* or *mûres de ronce*.

I doubt, however, that anyone would onfuse blackberries and mulberries in a lind tasting. Like all the bramble fruits, lackberries are each a collection of small, ndividual fruits with palpable internal eeds (they're drupelets, to be technical bout it, miniature versions of drupes such s peaches and plums). Mulberries are ofter and juicier and you don't notice the eeds. Mulberries are so delicate, in fact, hat they don't ship well at all and there-ore have never had a career in commerce s whole fruit. Most people who know bout mulberries today are aware of the lack variety and regard it as a nuisance of arly summer, a soft fruit that falls, goes mash, and stains cars. Washington, D.C., s annually deluged by messy black mul-erries. Articles appear in the *Washing-on Post* about coping with mulberries—pparently few people are clever enough o spread sheets under the trees (a tradi-ional harvest method) to collect fruit for ies, jam, sauce, or eating out of hand (see ecipes below).

In medieval times, people turned the taining powers of black mulberry to ac-ount. They used the juice as a dye and as food coloring in a sauce called murrey. Murrey was so widespread that several ecipes for it appear in the fourteenth-entury manuscripts collected in 1985 as *Curye on Inglysch*. There were even mock nurreys containing other colorants but no nulberry.

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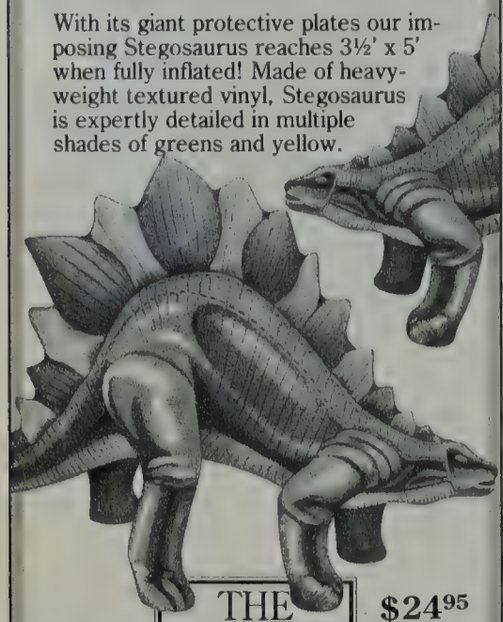

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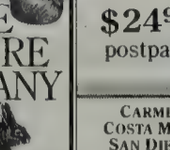

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But even in those days, there was no need for mulberry orchards: mulberries are easy to grow from seed or hardwood cuttings. And the most practical scheme was to plant a backyard tree, which would provide a convenient supply of fruit in late June or early July and attractive shade with its large leaves for the rest of the summer. This still holds for modern Americans, who can freeze the excess fruit, which needs no sugar or special treatment or parcooking. It goes into the freezer and comes out later unharmed, just like blueberries. But if you are going to plant a mulberry, taste the fruit of the tree you plan to take a cutting from. There is wide variation, and you might as well propagate good genes.

Once you start looking, you will have no trouble finding mulberries in this country. *M. rubra* is native, but its dark purple fruits are not deemed choice. The black and white European varieties, however, were imported in quantity, starting in the eighteenth century. Earlier attempts at mulberry culture had failed here, just as James I had failed to establish an English mulberry/silk industry.

One Jared Eliot introduced the white mulberry to the New World in the early 1700s. He knew that its leaves provided silkworms with optimal fodder from which to metabolize the fine threads for their cocoons. But those cocoons had to be toilsomely unwound and processed. So high labor costs torpedoed the infant silk industry in Connecticut and Pennsylvania. In Georgia, however, American silk flourished briefly. Experienced Italian silk growers accompanied James Oglethorpe's original colonists, and Georg silk was presented to the queen in 173 Yet the industry soon succumbed to ri and cotton.

This did not deter George Washingt from grafting English mulberries on n tive stock, nor did it discourage Thom Jefferson from planting a "mulberry ro or from ordering trees in 1789 fro France, "the best for silkworm."

The dream of an American silkwor industry died hard. American interest mulberries for silk peaked about 182 The sober author of *A History of Agricu ture in the State of New York (193* Ulysses Prentiss Hedrick, called it a craz

In 1824, a new mulberry was importe from the Philippines to France. *Mor multicaulis* sprouted at its base and pr vided silkworms with a fabulous abu dance of huge leaves. This tree w vaunted as the traditional feeding grou for Chinese silkworms. If Westerne grew it, they could then compete with t age-old Chinese silk industry. Hedri writes: "In 1826 William Prince and So proprietors of the Linnaean Gardens a Nurseries, Flushing, Long Island, i ported *Morus multicaulis* and began i propagation. It grew like a weed and i fame spread like wildfire."

Congress had already taken a stand favor of mulberry cultivation and sil worm breeding. The secretary of the tre sury published a 220-page manual 1828. State legislatures got on the ban wagon. And over the next twenty yea four specialty magazines were publishe including *Flushing Farmer and Silk Cu turist* and *Flushing Silk Journal*. Nu

Murrey

(Adapted orthographically from *Curye on Inglysch, English Culinary Manuscripts of the Fourteenth Century*, edited by Constance B. Hieatt and Sharon Butler, Oxford, 1985)

For to make murrey, tak mulberry and bray [pound] hem in a morter & wryng hem thorh a cloth, & do hem in a pot ouer the fyre; & do thereto bred & wyte gresse, & let yt nat boyle non ofter than onys. & do thereto a god perty [portion] of sugur, & if yt be not ynowe ycolowred [colored enough] bray mulburus; & serve yt forthe.

Pudding aux Mûres

(Adapted from Elizabeth David's version of Mme. de Seignobos's *Comment on forme une cuisinière*)

2½ cups sugar
2¼ pounds mulberries, preferably black mulberries
Stale white bread

1. Dissolve the sugar in 1¾ cups water over medium heat. Add the mulberries and cook until the fruit has completely softened and collapsed.
2. Push mulberry mixture through a sieve and let cool.
3. Meanwhile, cut the crusts off thin slices of white bread and fill a charlotte mold halfway up with the bread. Cut and arrange slices so that they fit the mold.
4. Pour in the mulberry mixture. Let the bread imbibe it. After 24 hours, you should end up with a dark red mass. If there is a pool of liquid on top, add a bit more bread and give the pudding another day.
5. Unmold the pudding on a serving platter. Serve with heavy cream.

Yield: 8 servings

ymen in New York State virtually
ndoned the propagation of other trees
l devoted themselves to the mulberry.
tree was worth more than a pound of
," writes Hedrick. "Nurserymen made
unes in a single season. It was said one
seryman grew 30,000 trees on a single
e which he sold at a profit of $30,000."
drick quotes a contemporary account
he mulberry frenzy:

ey met in solemn conclaves over bundles
Morus multicaulis twigs, discussing seri-
ly the glorious time when, in the not
tant future, every farm would be a nurs-
for the young trees, every house have
cocooneries attached. . . . The farmers'
es and daughters, when not engaged in
ding the worms, were to reel the silk, and
haps to spin and twist it, till silk should
come as cheap as cotton, and every ma-
n and maid rejoice in the possession of at
st a dozen silk dresses. It does not clearly
pear where and on what occasions they
re to wear these dresses, while their
ole time was to be occupied with the care
the silkworms and cocoons.

The boom collapsed by the fall of 1839.
sease and winter cold finished off the
lticaulis groves. All that remained
re the hardier standard species. And
y still remain, sometimes reaching a
ght of eighty feet and a girth of more
n sixteen. The mature mulberry is no
sh, you see, and it can produce a mon-
r amount of fruit. And then there are
curiously diverse leaves, sometimes
tched, sometimes lobed, sometimes of
ltiple shapes on the same tree, always
. They may remind you of the leaves of
ir kin the fig. By legend, a late Byzan-
e emperor saw a resemblance between
shape of a mulberry leaf and of south-
Greece, which he named Morea.

When you do locate a mulberry tree
ar you, watch for the first leaves to
out in the spring. They are latecomers,
d folk wisdom says that the appearance
mulberry leaves signals the end of frost
nger. Perhaps so, but they definitely do
ke a fine noise in the wind. The Bible
ests this natural phenomenon with
ma and divinity. It is written (I Chron.
:14–15):

erefore, David inquired again of God;
d God said unto him, Go not up after
m. Turn away from them, and come
on them over against the mulberry trees.
And it shall be, when thou shalt hear a
nd of marching in the tops of the mul-
rry trees, that then thou shalt go out to
ttle; for God is gone forth before thee to
ite the host of the Philistines.

*aymond Sokolov is a writer whose spe-
l interests are the history and prepara-
n of food.*

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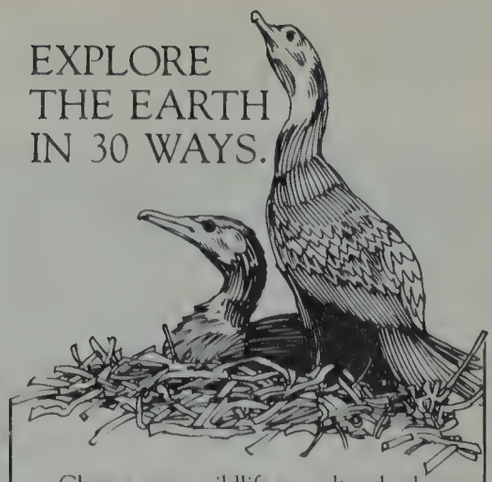

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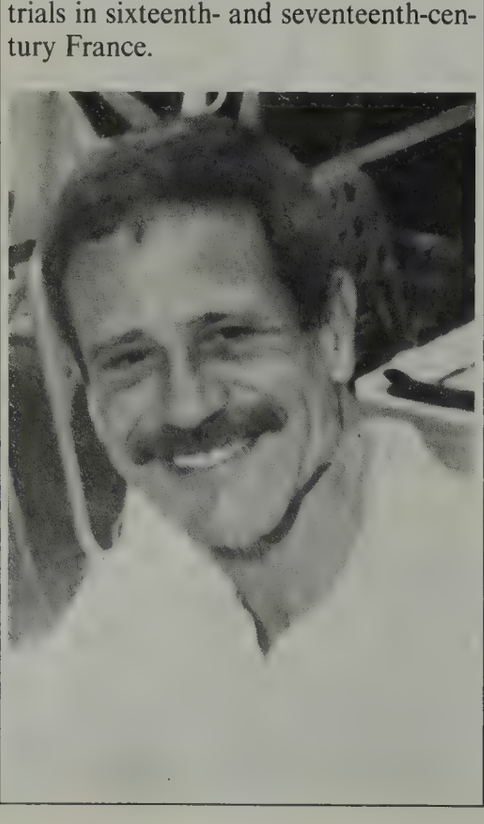
Their mating ardor made only steamier by the arrival of the wet season in the rain forest, this chorus of Caribbean frogs tried to make breeding a group affair. Such an occasion, known as multiple amplexus, is not uncommon among frogs, though it is unusual in this particular Trinidadian species, *Phyllomedusa trinitatis*. Instead of webbed feet it has distinct toes, one of which, like a human thumb, is opposable. The frogs crawl instead of hop, and they climb low bushes alongside pools in order to mate in the leaves overhanging the water. The female shapes the leaf into a rough tube with her feet and then deposits clumps of eggs, which the male fertilizes. When the eggs hatch, the weight of the tadpoles drops them from the leaf into the water below.—*B.D.S.*

Photograph
by Edward Rooks

Fewer than 200 witchcraft trials had been documented for France before historian **Alfred Soman** (page 6) spent eight years unearthing some 2,000 additional cases buried in that nation's archives. In order to transcribe the records, he had to become an expert at cracking the notoriously difficult handwritings of four centuries ago. Soman declares that as a result of this research he finds himself at odds with the prevailing interpretations of witch hunting in early modern Europe, such as Joseph Klaits's *Servants of Satan: The Age of the Witch Hunts* (Bloomington: Indiana University Press, 1985). For those interested in the subject, he recommends Christina Larner's *Enemies of God: The Witch Hunt in Scotland* (Baltimore: Johns Hopkins, 1981). On the persistence of witch beliefs in France today, there is *Deadly Words*, by Jeanne Favret-Saada (New York: Cambridge, 1981). Born in New York City, Soman received his doctorate from Harvard University and is now a research associate at the Centre National de la Recherche Scientifique in Paris. At present he is writing book-length studies of witchcraft and sodomy trials in sixteenth- and seventeenth-century France.



A visiting research scholar of South Asia studies at the University of Pennsylvania, **Jayashree B. Gokhale** (page 31) recounts that her connection to the Buddhist movement goes back to her childhood. "My father, B.G. Gokhale, had been asked by B.R. Ambedkar to establish a Buddhist studies department at Siddharth College, the educational institution of the People's Education Society in Bombay. I remember going to Siddharth College often. Even more vivid is my recollection of Buddhist temples and worship ceremonies we attended. The rooms were quiet, with fragrant smells and flowers. I thought I could learn a great deal about change in Indian society and the injustice in the social order by studying the untouchable Mahars," she says. Gokhale is now considering a career in law. For further information on the lives of untouchables she recommends *Untouchable*, by James M. Freeman (Stanford: Stanford University Press, 1979); *Competing Equalities: Law and the Backward Classes in India*, by Marc Galanter (Berkeley: University of California Press, 1984); and *The Politics of Untouchability*, by Owen Lynch (New York: Columbia University Press, 1969).

A member of the Isaac Newton scho of inspiration, **W. Carter Johnson** (pa 40) was eating lunch under an oak tree few years ago when he was pelted wi acorns discarded by blue jays above and thus his current project on blue j dispersal of nuts was born. In addition his jay research, Johnson (right), an ass ciate professor of botany at Virgin Polytechnic Institute and State Unive sity, has done fieldwork in the wetlan of the Great Plains and in the Sovi Union. Coauthor **Curtis S. Adkisso** (left) an associate professor of zoology Virginia Tech, studies jay–oak phenon ena, as well as the vocalizations finches, particularly crossbills and gr beaks. Future projects for Adkisson i clude work on the vocal dialects of alpi crossbills. Both Johnson and Adkisso enjoy fishing and hiking, but their fiel work abroad has turned them into li guists as well. Johnson has learned Ru sian; Adkisson studies German a Swedish. For further reading they su gest, "Remembrance of Seeds Stashed by Stephen Vander Wall and Russell Balda (*Natural History*, Septemb 1983), and "Ice Age Haven for Har woods," by Hazel R. Delcourt and Pa A. Delcourt (*Natural History*, Septe ber 1984). *Landscape Ecology*, by Ric ard T. Forman and Michael Godro (New York: John Wiley and Sons, In 1986), offers a good technical treatme of this relatively new science.

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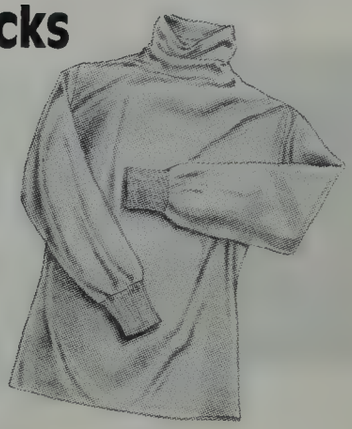

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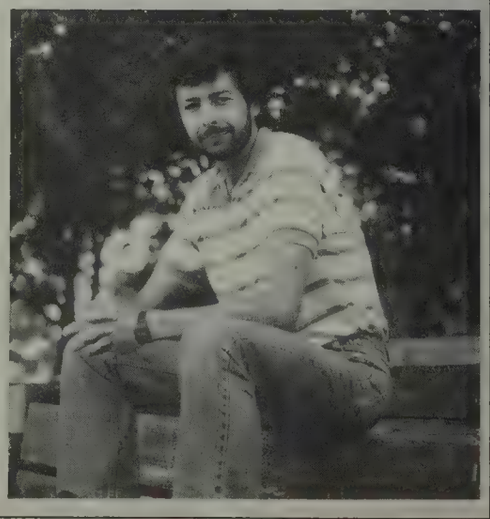
"I had a graduate degree in geology when I was hired at Columbia University in 1948," says **Marie Tharp** (page 48), but I never told anyone. I worked as part of a team, mainly as a draftsperson and map maker. We had a lot of fun and degrees didn't matter." Tharp translated, from numbers into profiles of the Mid-Atlantic Ridge, most of the data collected at sea by the late Bruce Heezen. She also went on research cruises herself. She and Heezen worked together on physiographic diagrams of the ocean floor, and together they realized that a rift must exist along the mountainous ridge. Tharp is now retired and spends much of her time gardening. **Henry Frankel**, who cooperated with Tharp on the rift article, teaches the philosophy of science at the University of Missouri-Kansas City. He met Tharp a few years ago, while searching for information about the discovery of the rift valley, a subject he wanted to write about. After talking with Tharp, he notes, "I suggested we coauthor a paper on the subject for presentation at the 1986 Baltimore meeting of the American Geophysical Union." The article in this issue of *Natural History* was adapted from that paper. For more information about the Atlantic Ridge, readers might look into *The Face of the Deep*, by B.C. Heezen and C.D. Hollister (New York: Oxford University Press, 1971), and *A Revolution in the Earth Sciences*, by Anthony Hallam (Cambridge: Cambridge University Press, 1973).

Author of *European Economic Prehistory: A New Approach* (New York: Academic Press, 1983), **Robin Dennell** (page 70) has been interested in the emergence of modern human behavior ever since his undergraduate days at Cambridge University. His archeological fieldwork includes excavation of neolithic and Bronze Age sites in Bulgaria, exploration of the history of irrigation in Iran, and study of the origins of plant domestication in Israel. A senior lecturer in prehistory at the University of Sheffield in England, Dennell now directs a paleolithic project for the British Archaeological Mission to Pakistan (the photograph shows him with 1.3-million-year-old animal remains discovered there recently). For introductions to human culture history, he recommends John Gowlett's *Ascent to Civilization: The Archaeology of Early Man* (New York: Knopf, 1984) and John E. Pfeiffer's *The Creative Explosion: An Inquiry into the Origins of Art and Religion* (New York: Harper and Row, 1982).

A native Texan, **Randy Moore** (page 64) was bound for medical school when a last minute course cancellation in his final semester at Texas A & M led him to enroll in a plant physiology class. He eventually became a botanist. An associate professor of biology at Baylor University in Waco, Texas, Moore earned his doctorate at UCLA. He recently sent plants into outer space on the space shuttle *Columbia* in an attempt to learn how plants grow and how their cells are altered in space. One of his current projects is a study of the ways in which plants perceive and respond to gravity. Moore has experienced the strong pull of gravity firsthand as a skydiver and also enjoys scuba diving, white water rafting, and rhythm-and-blues music. A detailed introduction to the natural history and cultivation of succulent plants can be found in *The Illustrated Encyclopedia of Succulents*, by Gordon Rowley (New York: Crown Publishers, Inc., 1978). For those who wish to delve into the biology, evolution, and ecology of cactus succulents, Moore recommends *The Cactus Primer*, by Arthur C. Gibson and Park S. Nobel (Cambridge: Harvard University Press, 1986).



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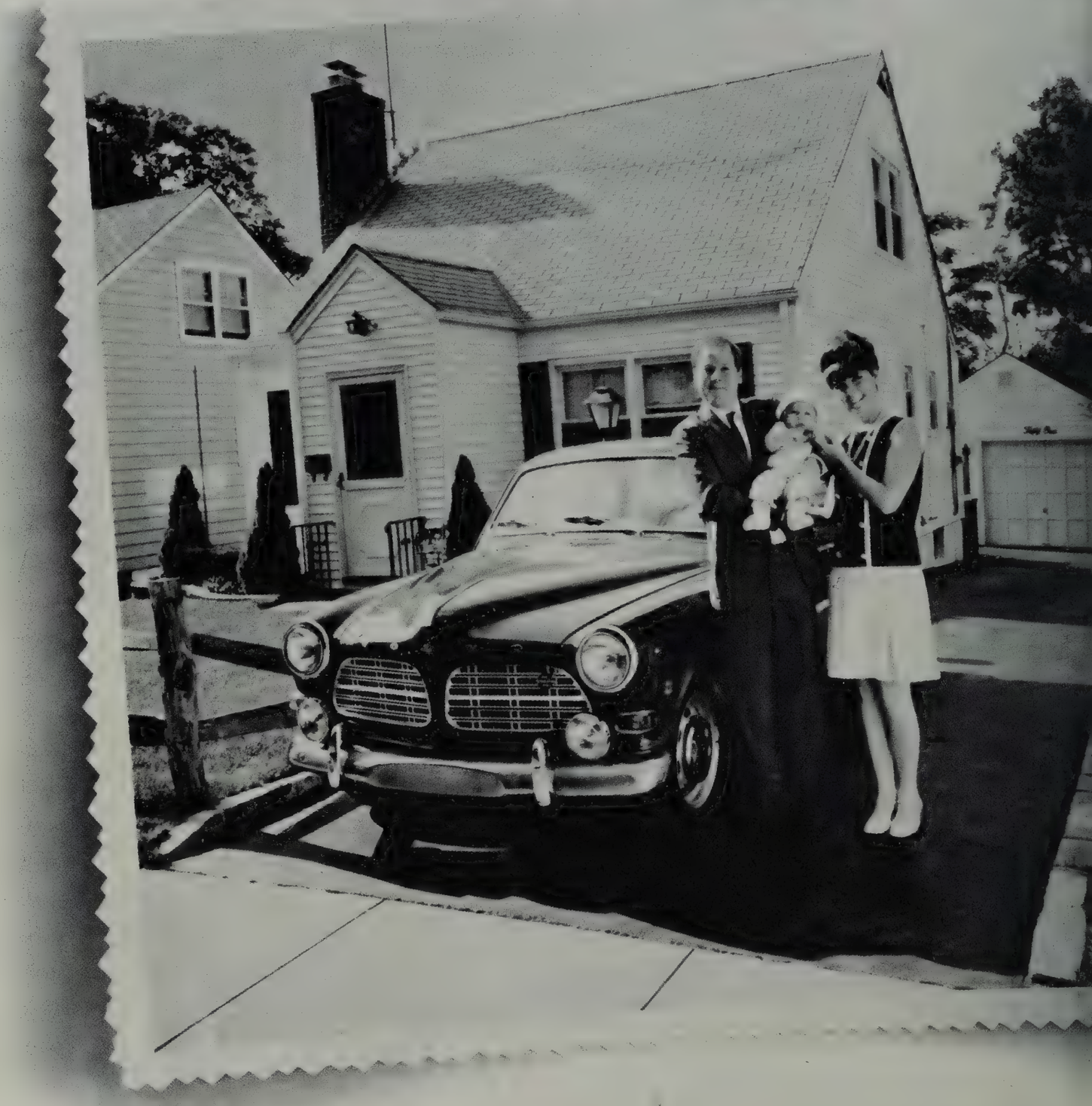

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4 Letters

8 The First Americans *Knut R. Fladmark*
Getting One's Berings

20 This View of Life *Stephen Jay Gould*
Of Kiwi Eggs and the Liberty Bell

30 How Dinosaurs Invented Flowers *Robert T. Bakker*
In the great plant wars of the Cretaceous period, the angiosperms had powerful allies.

40 Rhum Deal for Goats *Robin Dunbar*
A scientist learns that the single-minded pursuit of research—or sex—has its hazards.

48 The Anemone Below *Kenneth P. Sebens*
Good fences also make good neighbors underwater.

56 A Tale of Two Continents *Paul Tapponnier, photographs by Kevin Kling*
The collision of great landmasses and the death of a sea are parts of the geological drama that created the Himalayas.

66 Snake, Rattle, and Roll *David Duvall*
Prairie rattlesnakes often begin their migrations during severe thunder and rain storms, probably to avoid predators.

74 This Land *Robert H. Mohlenbrock*
Tionesta Forest, Pennsylvania

80 Celestial Events *Thomas D. Nicholson*
Mars and Jupiter Are Most Valuable Players

82 Reviews *Barry Maine*
How the North Was Won

90 The Living Museum
The Riddle of the Ridley

98 A Matter of Taste *Raymond Sokolov*
Hold the Caviar

104 The Natural Moment *Photograph by Tom Eisner*
Slugabed

106 Authors

Cover: *A feral billygoat on Scotland's Isle of Rhum. Story on page 40. Photograph by Laurie Campbell, Natural History Photographic Agency.*

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Encounters with the Agta

The story about the Agta tribe by Agnes Estioko-Griffin ("Daughters of the Forest," May 1986) brought back memories extending more than forty years into the past. I spent eight years in the Philippines (1939 to 1947) and have well over 200 photographs of the islands and their people.

In 1945 I became attached to the G-2 section of the 37th U.S. Infantry Division and participated as a civilian photographer in the liberation of the city of Baguio and the campaign through the Cagayan Valley from Santa Fe to Aparri in northern Luzon. During that time I had occasion to meet and photograph some of the "Pygmy Negrito tribe" (as they were known to us). We first met them east of Ilagan on the western slopes of the Sierra Madre, in uncharted territory. We called them the Bolo men, even though their primary weapons were their unmistakable bows and arrows. They were instrumental in causing the surrender of the part of the Japanese army that had withdrawn into the foothills of the Sierra Madre, in the habitat of those Estioko-Griffin identifies as the Agta tribe. At the time, we heard stories that the Bolo men were laying traps for the Japanese and sniping at them with their poison arrows, causing them no end of trouble.

I assume that the Agta and the Pygmy Negrito Bolo men and women are identical, but in 1945 we were unaware of the role women seem to play in the tribe's hunting practices. Estioko-Griffin's article brings a new dimension of understanding to this subject.

FRANZ UCKO
St. Paul, Minnesota

Agnes Estioko-Griffin replies:

The people in Franz Ucko's pictures certainly are Agta Negritos from the Sierra Madre on northern Luzon. I suspect that they represent different families than the Nanadukan people I wrote about and live to the south, on the western side of the mountains. There appears to have been some gene flow with non-Agta, since a few have straight hair. This is consistent with life on the Cagayan Valley side of the mountains. Most of the Agta in Ucko's photos are wearing bark cloth. Photographs from the same area, taken between

Both photographs from the collection of Franz Ucko

An American soldier observes the Agta performing a wedding dance in 1945. The man wearing a headband holds arrows with metal points.

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Franz Ucko with "the Bolo men," 1945

1905 and 1910, show similar bark-cloth attire. As early as 1936 Agta were wearing woven cloth in Casiguran, farther south still. Ucko's photographs nicely document the retention of the bark cloth.

The style of the bows and arrows, especially the arrowheads, is like that of the Agta I wrote about, with some important differences. In the photos, poison arrows (the ones in slim bamboo tube sheaths) are abundant, as are bamboo points, while metal points are unusual. Today poison arrows are almost never seen (though they were still in use as late as 1965), bamboo points are rare, and metal points common.

In the photos, only the men are carrying arrows. I am certain that then, as now, bow-and-arrow technology was primarily the province of men. While some women used the bow, many preferred, and still do favor, a long knife for killing. Women have never, in my many experiences, carried bows and arrows during family portrait sessions or during visits by strangers. Most non-Agta Filipinos would comment negatively or in a joking fashion on women using bows. Agta avoid criticism by non-Agta, and Filipinos definitely do not consider hunting a proper pursuit of women. I would bet my last dollar that some or all of these women joined the men in hunts or hunted by themselves.

Erratum: In Branley Allan Branson's article, "Is There Life After Strip Mining?" (August 1986) two insect genera were wrongly identified. The corrected sentences on page 35 should read: "The caddisfly genus known as *Hydroptila*, usually abundant in mountain streams, has not been seen in these streams for ten years. At the same time, *Hydropsyche*, a related genus, and usually far less abundant, survives. The difference is simply that *Hydropsyche* larvae have a less delicate breathing apparatus, along with the ability to get up on top of rocks and escape being smothered by silt."

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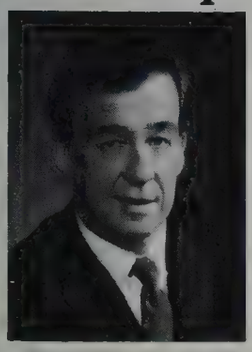

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Getting One's Berings

Even at the height of the last glaciation, human groups could have migrated into North America from Siberia

by Knut R. Fladmark

Editor's Note: Sixty years ago, archeologists began to report solid evidence that the ancestors of the American Indians hunted bison, mammoth, and other animals that roamed the New World during the last Ice Age. Natural History *was among the first to publish these discoveries, describing three sites in its May/June 1927 issue. The turning point for skeptics came that summer, when leading archeologists were invited to one of these sites—near Folsom, New Mexico—to inspect an arrowhead or spearpoint lodged between the ribs of an extinct bison. Additional finds of stone tools, now dated by laboratory tests, have since confirmed that humans lived in the New World at least 12,000 years ago, or 2,000 years before the end of the Ice Age. Many archeologists consider this date to be close to when the first migrants from Asia crossed into North America, since it falls after the peak of the last glaciation. They are also impressed by the swift extinction of the large mammals that these early Americans hunted. For others, however, tantalizing data from scattered sites suggest the New World was peopled earlier, and they anticipate a new turning point in archeological opinion. In a special series of articles,* Natural History *will explore some of these archeological sites and present other lines of research that bear on the current controversy.*

Most archeologists agree that people first entered the New World from northeast Asia by crossing the Bering Strait, which at various times in the past was an exposed land bridge. They argue a great deal, however, about when this critical crossover occurred. Well-dated archeological finds prove that humans lived in both North and South America by about 12,000 years ago, but the evidence for earlier sites remains controversial. One reason for the skepticism concerns the obstacles that past environmental conditions apparently placed in the paths of human migrants. The last Ice Age glaciers began receding only 14,000 years ago. How far into the New World could people have penetrated before then? And would they have needed a sophisticated technology and social organization to do so?

In the Pleistocene epoch—the last Ice Age—glaciers periodically covered large portions of the Northern Hemisphere, while sea levels and climate fluctuated. This epoch began about 1.6 million years ago and ended 10,000 years ago. The specific times scrutinized by most New World archeologists encompass a mild interval of reduced glaciation, known as the mid-Wisconsinan interglacial, which endured from approximately 60,000 to 25,000 years ago, and the final onslaught of ice that followed, known as the late Wisconsinan glaciation.

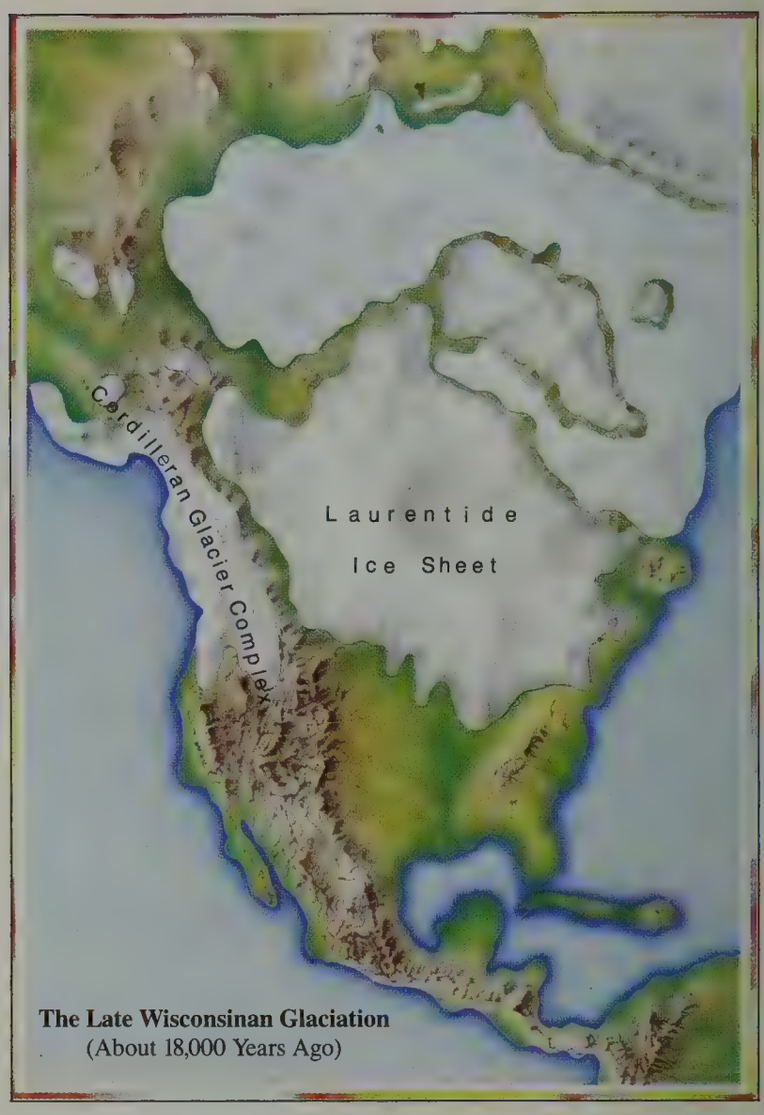
In the Old World, the interglacial interval was an important one in human physical and cultural evolution. In Europe, *Homo sapiens sapiens* evolved from or replaced *H. sapiens neanderthalensis*, and introduced a tool kit of stone blades, cave painting, and other less tangible social and cultural innovations. During the same period, humans reached Australia and Japan from the Asian mainland and may have occupied eastern Siberia for the first time. Theoretically, human groups could have migrated eastward through Beringia, the zone stretching from eastern Siberia across Alaska and the Yukon.

The only physical obstacle to such a migration would have been the absence of a continuous land bridge. With little water locked up in continental ice, sea levels during the mid-Wisconsinan climbed within thirty to sixty-five feet of their

All illustrations by Joe LeMonnier

Eighteen thousand years ago, humans migrating from northeast Asia (left) across the Bering land bridge (center) would have encountered extensive glaciation. Nevertheless, people could have penetrated deeply into North America (right) by passing through an ice-free corridor, which lay between the two principal ice masses, or by traveling along the coast in boats.

The Mid-Wisconsinan Interglacial
(About 40,000 Years Ago)



The Late Wisconsinan Glaciation
(About 18,000 Years Ago)

Between 60,000 and 25,000 years ago, Ice Age glaciers shrank, above, opening up potential migration routes from Asia to America. People may not have entered the New World, however, until after the height of the last glaciation, right.

---

present position, reducing the exposed land areas of all the continental shelves. The seaway through the Bering Strait was not as wide as it is today, but animals or people attempting to cross between Asia and America would have faced a stretch of water six to twelve miles wide. This was only a seasonal barrier, however, since it probably froze over in the winter.

Abundant fossil pollen and animal remains show that large parts of Beringia were covered by a grass- and herb-rich vegetation, a habitat called steppe-tundra. Animals that grazed there included mammoths, giant bison, and horses. From eastern Beringia, people could have moved south into the Interior Plateau of British Columbia, part of the Cordilleras, North America's western mountain system. Most major lowlands and valleys within these two regions were little affected by glaciers during the mid-Wisconsinan interval, and the climate, although somewhat cooler and drier, was much as it is today. The ice had also receded from the vast land area to the east, the Laurentian Plateau, except perhaps for an oscillating mass centered near what is now Hudson Bay and northern Quebec. To the northeast, in the Arctic archipelago, there were probably only local icecaps, interrupted by ice-free terrain and sea ice.

Any human populations traversing the northern half of the continent, from Beringia to what is now the conterminous United States, would have had to cope with a variety of habitats, including some comparable with contemporary tundra (the treeless plains characteristic of the Arctic) and boreal forests (dominated by spruce and fir). While they would have been able to make use of mammals of all sizes, as well as fish and mollusks, to survive in these environments, people almost certainly would have needed shelters, hide and fur clothing, watercraft, fire, and the ability to hunt in groups.

The modern subarctic forest is a harsh environment even for more recent, ethnographically recorded cultures, and its mid-Wisconsinan equivalent would have challenged tundra-adapted migrants from Beringia. In addition, the incentive to enter the forests may have been minimal, given the rich game resources of the steppe-tundra. For these reasons, humans could have moved into the New World but not far south. On the other hand, if there were any early boat-using peoples living along the Beringian coast, they could have easily exploited maritime resources along the entire west coast of North America, for there would have been no radical environmental differences for them to contend with as they moved south.

Whatever progress human groups may have made toward peopling the New World during the mid-Wisconsinan interglacial, conditions were radically altered with the onset of the late Wisconsinan glaciation. The glaciation would have affected the movement of any people already in North America, as well as constrained migration from eastern Siberia.

The traditional picture of glaciation in North America in the late Pleistocene is of ice accumulating slowly in two or three major centers and building toward massive, domed icecaps centered over Hudson Bay (the Laurentide ice sheet) and the Interior Plateau of British Columbia (the Cordilleran glacier complex). This process is usually thought to have begun more than 70,000 years ago; to have weakened, halted, or even reversed during the mid-

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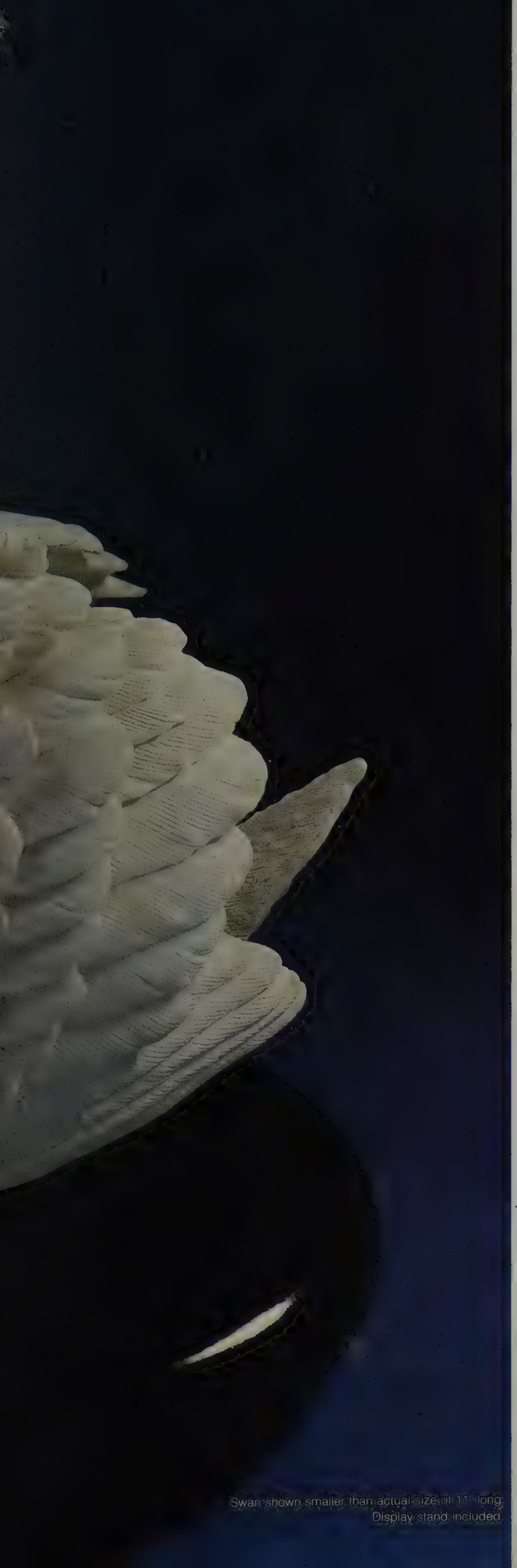

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Wisconsinan interglacial; and to have been vigorously renewed 25,000 or 30,000 years ago. The Cordilleran glaciers (to the west) and the Laurentide ice sheet (to the east) are traditionally thought to have eventually coalesced, burying the northern part of the continent in ice and forming a barrier between Beringia and what is now the conterminous United States.

In contrast, some researchers now advocate a markedly different style, rate, and magnitude of glaciation. They propose that ice accumulated much more rapidly than once thought but that the ice sheets were not as thick or as extensive as previously suspected. Further, many geologists believe that a number of independent ice masses coalesced to form the Laurentide ice sheet and that ice never completely covered the high Arctic region. Finally, they conclude that glaciation in North America peaked at different times in the various regions. While parts of the Laurentide ice sheet were already at their maximum extent sometime between 22,000 and 18,000 years ago, the Cordilleras in the vicinity of present-day British Columbia were just starting their major glacial accumulation, and significant ice had not yet built up in the eastern and central Arctic. In other words, the regions that underwent glaciation were not all uninhabitable at the same time.

During the late Wisconsinan, the sea level fell to perhaps 280 feet below its present level (estimates vary widely) because of the large amount of water locked up in glacial ice. As a result, Beringia became a continuous land bridge, broadened by the emergent shelves of the Bering and Chukchi seas. The region remained mostly ice free, since glaciers developed in mountains but generally not in the interior lowlands. Ice damming caused the formation of glacial lakes in the northern Yukon, but most of the central Yukon basin remained unobstructed.

Archeologists formerly thought that during the late Wisconsinan Beringia continued to be dominated by a steppe-tundra environment well suited to the spread of big game hunting cultures from central Asia to North America. Recently, however, some scientists have challenged this assumption. Pollen cores from easternmost Beringia, close to the Laurentide ice front, show that 30,000 to 14,000 years ago, the landscape consisted of relatively bare polar desert or of fell-field tundra, a rocky terrain sparsely vegetated by herbs and dwarf shrubs. This suggests that the late Wisconsinan environment in this part of Beringia was as harsh as the modern high Arctic. Further, when the analysis is based strictly on dated fossil finds, it turns out that there were fewer and less diverse large animal species in Beringia during the glacial climax than in mid-Wisconsinan times. Central Alaska may have supported bison, musk oxen, woolly mammoth, and a few lesser species, while easternmost Beringia may have sustained only musk oxen and smaller mammals.

Sometimes lost in descriptions of Beringia, however, is the realization that the famous land bridge had coastlines as well as interior plains. Given relatively modest big game populations inland, the ocean shores may have been very important to any human inhabitants. In particular, the unfrozen Pacific coast was presumably a rich zone. Sheltered habitats near sea level probably supported a diverse vegetation, while rocky headlands would have been rookeries for sea birds. Estuaries and lower courses of rivers would have experienced major salmon runs. Scouring by seasonal shore ice might have reduced some resources, such as clam and mussel beds, but this was probably compensated for by changes in the distribution and migration patterns of sea mammals affected by closure of the Bering Strait. Whales and seals, which now migrate into and through the Bering Strait from the Pacific, must have been confined to the southern shore, while walrus and other species, now limited to the zone of seasonal sea ice in the Bering and Chukchi seas, were probably also displaced to the southern Beringian coast. Unfortunately, most direct evidence for this coastal environment is now drowned beneath seas or obscured by problematical dating.

To the northeast of Beringia, there may have been some ice-free Arctic landmasses, but they were probably not suitable for human habitation. The late Wisconsinan glacial climax in the Cordilleras, to the south of Beringia, was apparently short-lived. The southern margins of the Cordilleran ice apparently advanced sometime between 20,000 and 17,000 years ago and retreated 12,000 or 13,000 years ago. Before and after these times, large areas of terrain were ice free and potentially biologically productive. As late as 17,000 years ago, mammoths were grazing near what is now Victoria, and glaciers did not reach the west coast of Vancouver Island until later.

In the Laurentian Plateau, the late Wisconsinan maximum glacial extent is traditionally assumed to have consisted of the formation of a huge continental icecap centered near Hudson Bay. The ice sheet is sometimes pictured as domelike, with sloping surfaces rising toward central ridges or divides up to two and a half miles thick. Although a great ice mass with fro-

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zen summits looming over eastern and central North America is a picturesque concept, and one accepted without much debate until recently, there are several problems with it.

First, there is no direct evidence that the ice was very thick at the center of the Laurentide ice sheet. Nor do any known climatic processes seem sufficient to account for the rapid development and abrupt disintegration of so thick a mass. Although the final recession may be pictured in terms of icebergs breaking off into the oceans and lakes, a more economical solution may be simply to assume an initially thinner and less monolithic Laurentide glaciation. Finally, while there appears little doubt that at its maximum the Laurentide ice sheet was a very extensive ice mass, the maximum line that has been determined, from southeastern Alberta to the Atlantic seaboard, does not represent a single synchronous advance. While the precise events are under debate, lobes of the glacier in different places reached the maximum line at different times.

Plant and animal life of the North American interior suffered as late Wisconsinan glaciers developed and the climate became cooler. Major regions, however, did not necessarily become devoid of life until actually covered by ice. Around the Great Lakes, late Wisconsinan glaciers advanced into living pine-spruce-alder forests, as suggested by trees with bark, buried in till, that are bent in U-shapes as though still green and fresh when they were overridden. Most mammalian populations, including any humans, could have simply shifted their ranges as the ice-free area between the Cordilleran and Laurentide ice masses slowly contracted. Occasionally, animals might have continued to occupy regions right up to the ice fronts, but generally they probably responded in advance to such indirect factors as lowering temperatures, changes in plant communities or vegetation cover, and drainage changes.

Relatively rapid glaciation could have forced any people in the midcontinental region back into Beringia instead of southward, while a slow, radial expansion of Laurentide glaciers might have encouraged a gradual displacement of populations in all directions beyond the ice limits. The Laurentide ice sheet probably made its westernmost advance in the region between 55° and 60° north latitude. Ice across this area, if it abutted Cordilleran glaciers, could have acted as a barrier, with plants and animals (perhaps including people) caught north of the closure point confined toward the north and west, and those present south of the contact

progressively displaced toward the south and west. Such conditions may have been reached 22,000 years ago and persisted until as late as 14,500 years ago.

As an alternative to this barrier, an "ice-free corridor" runs through the minds of many archeologists, like a highway beckoning Paleo-Indians south from Beringia. There is increasing evidence that even during the glacial climax, a strip of ice-free terrain persisted between the Cordilleran glacier complex and the Laurentide ice sheet. Late Wisconsinan Cordilleran glaciers seem to have been confined to mountain and foothill valleys, leaving extensive upland and alpine areas along the east side of the Continental Divide free of ice. Even if ice did coalesce in the corridor, it probably acted as a barrier for only a short time during the glacial climax.

While geological data support the concept of a midcontinental corridor, it must have been a forbidding area. Anyone who has clambered over loose piles of rock rubble and skirted meltwater streams and ponds to reach the steep-crevassed and dripping front of even a small modern glacier needs no convincing that massive Pleistocene ice fronts must have been oppressive. In places, lakes may have filled the corridor between the Cordilleran and Laurentide ice. Although they would have frozen in winter, allowing animals or people to cross them, these lakes could only have been hostile to human habitation. Cold, berg-laden, and with unstable shorelines and fluctuating water levels, they were probably biologically sterile.

Considering that, at best, a certain portion of the corridor would have been occupied by raw morainal deposit, meltwater lakes, stagnant and buried ice blocks, and rugged mountain slopes, living conditions there must have been marginal. South-facing slopes and uplands may have supported enough vegetation for musk oxen, and bird-resting and -feeding areas may have existed along the corridor, inducing humans to enter the zone (currently, a major intercontinental bird flyway parallels this route). There are, however, no significant faunal remains dated to the late Wisconsinan in the crucial central and northern portions of the corridor.

While debate has focused on this daunting ice-free corridor as a route by which early human populations could have made their way south from Beringia during maximum late Wisconsinan glaciation, the northwest coast presented a more favorable route. Southern Cordilleran glaciers achieved their final 60 to 120 miles of extension for only a moment of geological time, sometime between 17,000 and 14,500 years ago. At the very least, there-

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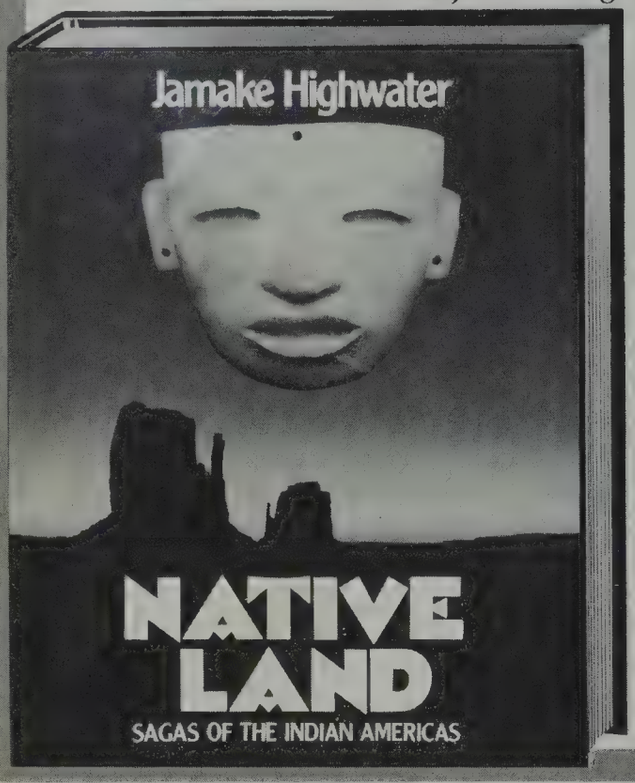

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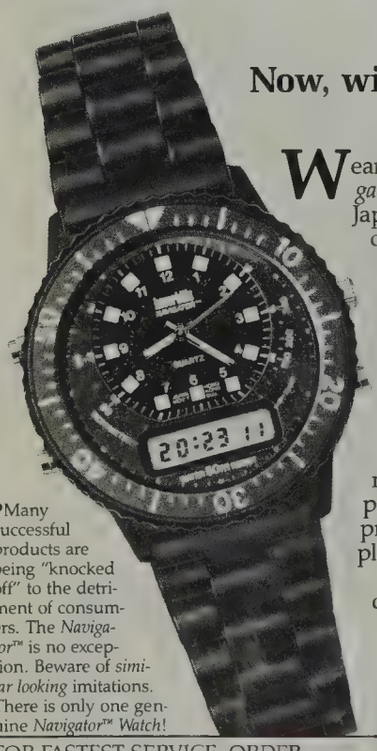

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fore, the northwest coast was habitable longer than the midcontinental area, remaining available for some of the time that the corridor was near maximum closure. More speculatively, even at the height of glaciation, a discontinuous strip of unglaciated headlands, uplands, and islands was probably spared by the relatively weak and brief ice advance to the outer coast, coupled with lowered sea levels. The North Pacific Ocean did not permanently freeze during the last glaciation, although seasonal sea ice may have formed in sheltered bays and inlets. Thus, any inhabitants of shoreline refuges would have had access to intertidal resources (found between low- and high-tide marks) and marine resources almost as rich as the bounty for which the northwest coast is historically famous.

Assuming that maximum glaciation on the Pacific side of Beringia and along the northwest coast consisted only of valley lobes that terminated at or near sea level, people could have made the trip south along the coast by crossing the ends of the glaciers on foot. Although the possibility is rarely considered, there is no reason why people in Pleistocene times could not have crossed glaciers for relatively short distances, where sufficient motivation existed. More likely, however, any groups negotiating this hypothetical route would have used boats—expected equipment for people oriented to fishing, shellfish collecting, and possibly sea-mammal hunting. Unfortunately, the antiquity and effectiveness of Pleistocene watercraft are still unknown, despite indications that water travel brought a viable human population to Australia about 40,000 years ago. People moving by watercraft leave few archeological traces, especially if that movement is rapid, and theoretically, even primitive boats could have traversed the entire Pacific coast of North and South America in less than ten years.

Human groups attempting to move south through the North American interior during the late Wisconsinan would have needed to know how to keep warm and fed in the harshest of environments. Coastal peoples, on the other hand, would have benefited from the continuity in coastal and maritime resources, including some, such as shellfish, that could be harvested with simple technology. In addition, relatively mild climates and water travel would have eased the movement of bands of mixed age and sex.

Conditions for human migration began to change yet again about 14,000 years ago. This was a time of abrupt, worldwide climatic warming, with glacial margins beginning an oscillating retreat. By 11,000

or 12,000 years ago, the environment was adequate to permit human occupation well within the previous maximum glacial boundaries, and 2,000 years later, all the ice sheets were greatly diminished.

As the glaciers melted, there was a rapid rise in world sea levels. The Bering Strait developed as a narrow seaway and became a significant barrier by about 12,000 years ago. The large volumes of meltwater also created lakes and outwash drainages. Virtually all of central and southern Alberta, Saskatchewan, and Manitoba are mantled with lake sediments, reflecting the importance of these environments during the early postglacial period. Initially, cold temperatures, high sediment loads, sporadic changes in water level and in the flow of meltwater, and isolation from more mature aquatic ecosystems would have kept these lakes biologically poor.

People would have found it difficult to disperse south of Beringia at this time without watercraft capable of negotiating the broad rivers and lakes, but there is no reason to suppose they lacked the needed technology. Despite a watery landscape, the potential for human habitation in the midcontinental area was good beginning 13,000 or 14,000 years ago. Ground freshly freed of ice would have been bare and raw, but with warming temperatures, a major limitation on plant and animal life lifted and recolonization probably proceeded rapidly. In many portions of the Laurentian Plateau, freshly exposed ground seems to have been first colonized by grassy, tundralike vegetation, followed by spruce-dominated forests. The presence of spruce forest in the central and northern corridor by about 11,500 years ago suggests that the area sustained grasslands well before that time.

As the glaciers withdrew, an interval may have existed—before forests intervened—in which grasslands formed a continuous ecological link from Beringia to central North America. Because of the warmer temperatures, abundant water, and significantly receded ice margins, this might have been an optimal, albeit brief, interval (from 13,000 to 12,000 years ago) for animals and humans to expand throughout the continent. Nevertheless, human migration into North America cannot be proved environmentally impossible for any time during the last 60,000 years. Even during the least favorable period—the climax of the last glaciation, from 18,000 to 15,000 years ago—a route along the northwest coast seems to have been feasible, and a corridor between the Laurentide and Cordilleran ice masses may also have been available. □

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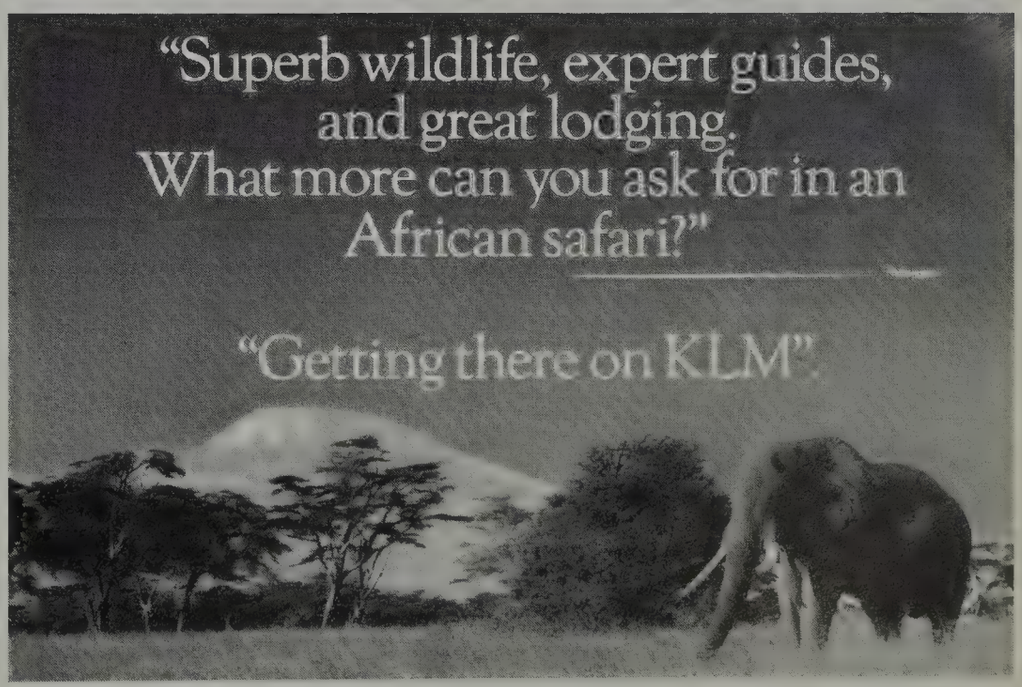

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by Stephen Jay Gould

Like Ozymandias, once king of kings but now two legs of a broken statue in Percy Shelley's desert, the great façade of Union Station in Washington, D.C., stands forlorn (but ready to front for a bevy of yuppie emporia now under construction), while AMTRAK now operates from a dingy outpost at the side. Six statues, portraying the greatest of human arts and inventions, grace its parapet. Electricity holds a bar of lightning; his inscription proclaims: "Carrier of light and power. Devourer of time and space .... Greatest servant of man .... Thou hast put all things under his feet."

Yet I will cast my vote for the Polynesian double canoe, constructed entirely with stone adzes, as the greatest invention for devouring time and space in all human history. These vessels provided sufficient stability for long sea voyages. The Polynesian people, without compass or sextant, but with unparalleled understanding of stars, waves, and currents, navigated these canoes to colonize the greatest emptiness of our earth, the "Polynesian triangle," stretching from New Zealand to Hawaii to Easter Island at its vertexes. They sailed forth into the open Pacific more than a thousand years before Western navigators dared to leave the coastline of Africa and make a beeline across open water from the Guinea coast to the Cape of Good Hope.

New Zealand, southwestern outpost of Polynesian migrations, was so isolated that not a single mammal (other than bats and seals with their obvious means of transport) had managed to intrude. New Zealand was a world of birds, dominated by several species (thirteen to twenty-two by various taxonomic reckonings) of large, flightless moas. Only *Aepyornis*, the extinct elephant bird of Madagascar, ever surpassed the largest moa, *Dinornis maximus*, in weight. Ornithologist Dean Amadon estimated the average weight of *D. maximus* at 520 pounds (although some recent revisions nearly double this bulk), compared with about 220 pounds for ostriches, the largest living birds.

We must cast aside the myths of noble non-Westerners living in ecological harmony with their potential quarries. The ancestors of New Zealand's Maori people based a culture on hunting moas, but soon made short work of them, both by direct removal and by burning of habitat to clear areas for agriculture. A 500-pound chicken was surely too much to resist.

Only one species of New Zealand ratite has survived. (Ratites are a closely related group of flightless ground birds, including moas, African ostriches, South American rheas, and Australian-New Guinean emus and cassowaries. Flying birds have a keeled breastbone, providing sufficient area for the attachment of massive flight muscles. The breastbones of ratites lack a keel, and their name honors that most venerable of unkeeled vessels, the raft, or *ratis* in Latin.) We know this curious creature more as an icon on tins of shoe polish or as the moniker for New Zealand's human inhabitants—the kiwi, only hen sized, but related most closely to moas among birds.

Three species of kiwis inhabit New Zealand today, all members of the genus *Apteryx* (literally, wingless). Kiwis lack an external tail, and their vestigial wings are entirely hidden beneath a curious plumage—shaggy, more like fur than feathers, and similar in structure to the juvenile down of most other birds. (Prized by Maori hunters, the feathers were used to make the beautiful cloaks once worn by chiefs; but the small, secretive, and widely ranging nocturnal kiwis managed to escape the fate of their larger moa relatives.)

The furry bodies, with even contours unbroken by tail or wings, are mounted on stout legs—giving the impression of a double blob (small head and larger body) on sticks. Kiwis eat seeds, berries, and other parts of plants, but they favor earthworms. Their long, thin bills probe the soil continually, suggesting the oddly reversed perspective of stick leading blind man. This stick, however, is richly endowed as a sensory device, particularly as an organ of smell. The bill, uniquely among birds, bears long external nostrils, while the olfactory bulb of kiwi brains is second largest among birds relative to size of the forebrain. A peculiar creature indeed.

But the greatest of kiwi oddities center upon reproduction. Females are larger than males. They lay one to three eggs and may incubate them for a while, but they leave the nest soon thereafter, relegating to males the primary task of incubation, a long seventy to eighty-four days. Males sit athwart the egg, body at a slight angle and bill stretched out along the ground. Females may return occasionally with food, but males must usually fend for themselves, covering both eggs and nest entrance with debris and going forth to forage once or twice on most nights.

The kiwi egg is a wonder to behold, and the subject of this column. It is, by far, the largest of all bird eggs relative to body size. The three species of kiwis just about span the range of domestic poultry: the largest about the size of Rhode Island Reds; the smallest similar to bantams—say five pounds as a rough average (pretty meaningless, given the diversity of species, but setting the general domain). The eggs range to 25 percent of the female's body weight—quite a feat when you consider that she often lays two, and sometimes three, in a clutch, spacing them about thirty-three days apart. A famous X-ray photo of a kiwi and egg taken at the kiwi sanctuary of Otorohanga, New Zealand, tells the tale more dramatically than any words I could produce. The egg is so large that females must waddle, legs spread far apart, for several days before laying, as the egg passes down the oviduct toward the cloaca. The incubation patch of male kiwis extends from the top of the

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chest all the way down to the cloaca—in other words, they need almost all their body to cover the egg.

A study of the general relationship between egg size and body size among birds shows that average birds of kiwi weight lay eggs weighing from 55 to 100 grams (as do domestic hens). Eggs of the brown kiwi weigh between 400 and 435 grams (about a pound). Put another way, an egg of this size would be expected from a twenty-eight pound bird, but brown kiwis are about six times as small.

The obvious question, of course, is why? Evolutionary biologists have a traditional approach to riddles of this sort. They seek some benefit for the feature in question, then argue that natural selection has worked to build these advantages into the animal's way of life. The greatest triumphs of this method center upon odd structures that seem to make no sense or (like the kiwi egg) appear, prima facie, to be all out of proportion and probably harmful. After all, anyone can see that a bird's wing (although not a kiwi's) is well designed for flight, so reference to natural selection teaches you little about adaptation that you didn't already know. Thus, the test cases of textbooks are apparently harmful structures that, on closer examination, confer crucial benefits upon organisms in their Darwinian struggle for reproductive success.

This general strategy of research suggests that if you can find out what a structure is good for, you will possess the major ingredient for understanding why it is so big, so colorful, so peculiarly shaped. Kiwi eggs should illustrate this basic method. They seem to be too big, but if we can discover how their large size benefits kiwis, we shall understand why natural selection favored large eggs. Readers who have followed these columns for some time will realize that I wouldn't be writing about this subject if I didn't think that this style of Darwinian reasoning embodied a crucial flaw.

The flaw lies not with the claim of utility. I regard it as proved that kiwis benefit from the unusually large size of their eggs—and for the most obvious reason. Large eggs mean large and well-developed chicks that can fend for themselves with a minimum of parental care after hatching. Kiwi eggs are not only large; they are also the most nutritious of all bird eggs for a reason beyond their maximal bulk: they contain a higher percentage of yolk than any other egg. Brian Reid and G.R. Williams report that kiwi eggs may contain 61 percent yolk and 39 percent albumin (or white). By comparison, eggs of so-called precocial species (with downy young hatching in an active, advanced, and open-eyed state) contain 35 to 45 percent yolk; while eggs of altricial species (with helpless, blind, and naked hatchlings) carry only 13 to 28 percent yolk.

The life style of kiwi hatchlings demonstrates the benefits of their large, yolky eggs. Kiwis are born fully feathered and usually receive no food from their parents. Before hatching, they consume the unused portion of their massive yolk reserve and do not feed (but live off these egg-based supplies) for their first seventy-two to eighty-four hours alfresco. Newly hatched brown kiwi chicks are often unable to stand because their abdomens are so distended with this yolk reserve. They rest on the ground, legs splayed out to the side, and only take a first few clumsy steps when they are some sixty hours old. A chick does not leave its burrow until the fifth to ninth day when, accompanied by its father, it sallies forth to feed sparingly.

Kiwis thus spend their first two weeks largely living off the yolk supply that their immense egg has provided. After ten to fourteen days, the kiwi chick may weigh one-third less than at hatching—a fasting marked by absorption of ingested yolk from the egg. Brian Reid studied a chick that died a few hours after hatching. Almost half its weight consisted of food reserves—112 grams of yolk and 43 grams of body fat in a 319 gram hatchling. Another chick, killed outside its burrow five to six days after hatching, weighed 281 grams and still held almost 54 grams of enclosed yolk.

I am satisfied that kiwis do right well by and with their large eggs. But can we conclude that the outsized egg was built by natural selection in the light of these benefits? This assumption—the easy slide from current function to reason for origin—is, to my mind, the most serious and widespread fallacy of my profession, for it

In Otorohanga, New Zealand, a North Island brown kiwi was X-rayed one day before it laid its egg at the Otorohanga Kiwi House and Native Bird Park.
Otorohanga Zoological Society

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lies embedded in hundreds of conventional tales about pathways of evolution. I like to identify this error of reasoning with a phrase that ought to become a motto: current utility may not be equated with historical origin, or, when you demonstrate that something works well, you have not solved the problem of how, when, or why it arose.

The reason for labeling an automatic inference from current utility to historical origin as fallacious is simple: good function has an alternative interpretation. A structure now useful may have been built by natural selection for its current purpose (I do not deny that the inference often holds in fact), but it may also have developed for another reason (or for no particular reason at all in terms of function) and then been co-opted for its present use. The giraffe's neck either got long in order to feed on succulent leaves atop acacia trees or it elongated for a different reason (perhaps unrelated to any adaptation of feeding), and giraffes then discovered that, by virtue of their new height, they could reach some delicious morsels. The simple good fit of form to function—long neck to top leaves—permits, in itself, no conclusion about why giraffes developed long necks. Since Voltaire understood the foibles of human reason so well, he allowed the venerable Dr. Pangloss to illustrate this fallacy in a solemn pronouncement:

> Things cannot be other than they are .... Everything is made for the best purpose. Our noses were made to carry spectacles, so we have spectacles. Legs were clearly intended for breeches, and we wear them.

This error of sliding too easily between current use and historical origin is by no means a problem for Darwinian biologists alone, although our faults have been most prominent and unexamined. It pervades all fields that try to infer history from our present world. My favorite current example is a particularly ludicrous interpretation of the so-called anthropic principle in cosmology. Many physicists have pointed out—and I fully accept their analysis—that life on earth fits intricately with physical laws regulating the universe, in the sense that, were various laws even slightly different, molecules of the proper composition and planets with the right properties could never have arisen—and we would not be here. From this analysis, a few thinkers have drawn the wildly invalid inference that human evolution is therefore prefigured in the ancient design of the cosmos—that the universe, in Freeman Dyson's words, must have known we were coming. But the current fit of human life to physical laws permits no conclusion about the reasons and mechanisms of our origin. Since we are here, we have to fit; we wouldn't be here if we didn't—though something else would, probably proclaiming, with all the hubris that a diproton might muster, that the cosmos must have been created with its later appearance in mind. (Diprotons are a prominent candidate for the highest bit of chemistry in another conceivable universe.)

But back to kiwi eggs. Most literature has fallen into the fallacy of equating current use with historical origin, and has defined the problem as explaining why the kiwi's egg should have been actively enlarged from an ancestor with an egg more suited to the expectations of its body size. Yet University of Arizona biologist William A. Calder III, author of several excellent studies on kiwi energetics, has proposed an opposite interpretation that strikes me as much more likely (though I think he has missed two or three good arguments for its support, and I shall try to supply them here). (See his article, "The Kiwi," *Scientific American*, July 1978; also *Bioscience* for August 1979, and his recent book, *Size, Function and Life History*, Harvard University Press, 1984, pp. 335–38 on kiwi eggs).

The alternative interpretation holds that kiwis are phyletic dwarfs, evolved from a lineage of much larger birds. Since these large ancestors laid big eggs appropriate to their body size, kiwis just never (or only slightly) reduced the size of their eggs as their bodies decreased greatly in bulk. In other words, kiwi eggs never became unusually large; kiwi bodies got small—and these statements are not equivalent, just as we know that an obese man is not short for his weight, despite the old jest.

(Such a hypothesis is not anti-adaptationist in the sense that maintenance of a large egg as size decreases—and in the face of energetic and biochemical costs imposed by such a whopping contribution to the next generation—may well require a direct boost from natural selection to prevent an otherwise advantageous decrease more in keeping with life at Colonel Sanders's favorite size. Still, there is a world of difference between retaining something you already have, and first developed for other reasons [in this case simple appropriateness for large body size], and actively evolving such a unique and cumbersome structure for some special benefit.)

Calder's interpretation might seem forced or far-fetched but for the outstanding fact of taxonomy and biogeography that began this column. Moas are the closest cousins of kiwis, and most moas were very large birds. "Is the kiwi perhaps a shrunken moa?" Calder asks. Unfortunately, all moa fossils lie in rocks of a geological yesterday, and kiwi fossils are entirely unknown—so we have no direct evidence about the size of ancestral kiwis. Still, I believe that all the inferential data support Calder's alternative hypothesis for the great size of kiwi eggs—a "structural" or "historical" explanation if you will, not a conventional account based on natural selection for immediate advantages.

Although the best argument for viewing kiwis as much smaller than their ancestors must be the large size of their closest moa cousins, Calder has also developed a quirky and intriguing speculation to support the dwarfed status of kiwis. (I hasten to point out that neither of these arguments is more than a reasonable conjecture. All evidence can be interpreted in other ways. Both moas and kiwis, for example, might have evolved from a kiwi-sized common ancestor, with moas enlarging later. Still, since the kiwi is the smallest of all ratites—a runt among ostriches, rheas, emus, and cassowaries—its decrease seems more probable than moa increase. But we will not know until we have direct evidence of fossil ancestry.)

Calder notes that in many respects, some rather curious, kiwis have adopted forms and life styles generally associated with mammals, not birds. Kiwis, for example, are unique among birds in retaining ovaries on both sides (the right ovary degenerates in all other birds)—and eggs alternate between sides, as in mammals. The seventy- to eighty-four-day incubation period matches the eighty-day pregnancy expected for a mammal of kiwi body size, not the forty-four days predicted for birds of this weight. Calder continues: "When one adds to this list, the kiwi's burrow habit, its furlike body feathers, and its nocturnal foraging highly dependent on its sense of smell, the evidence for convergence seems overpowering." Of course, this conjunction of traits could be fortuitous and each might mean something quite unmammalian to a kiwi, but the argument does gain strength when we remember that no terrestrial mammals reached New Zealand, and that the success of many introduced species indicates a hospitable environment for any creature that could exploit a mammalian way of life.

You will be wondering what this could possibly mean for my key claim that kiwis are probably descendants of much larger birds. After all, mammals are superior, noble, and large. But they aren't. The original and quintessential mammalian way of

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life (still exploited by a majority of species) is secretive, furtive, nocturnal, smell oriented in a nonvisual world—and, above all, small. Remember that for two-thirds of their geological history, all mammals were little creatures living in the interstices of a world ruled by dinosaurs. If a large bird converged upon a basically mammalian life style in the absence of "proper" inhabitants as a result of geographic isolation, *decrease* in size would probably be a first and best step.

Perhaps I have convinced you that kiwis probably decreased in size during their evolution. But why should this dwarfing help to explain their large eggs? Why didn't egg size just keep pace with body size as kiwis scaled down? We now come to the strong evidence of the case.

The study of changes in form and proportion as organisms increase or decrease in size is called allometry. It has been a popular and fruitful subject in evolutionary research since Julian Huxley's pioneering work of the 1920s. One of Huxley's own classic studies (*Journal of the Linnaean Society of London*, vol. 36, 1927, pp. 457–66) bore the title: "On the Relation Between Egg-weight and Body-weight in Birds." Huxley found that if you plot one point for each species on the hummingbird-to-moa curve for egg weight versus body weight, relative egg size decreases in an even and predictable way. The eggs of large birds, he found, are absolutely larger, but relatively smaller in proportion to body weight, than those of small birds.

Huxley's work has since been extended several times with more voluminous and consistent data. In the two best studies that I know, Samuel Brody (in his masterful compendium, *Bioenergetics and Growth*, 1945) calculated a slope of 0.73, while H. Rahn, C.V. Paganelli and A. Ar (*The Auk*, vol. 92, 1975, pp. 750–65), with even more data from some 800 species, derived a similar value of 0.67. This means that as birds increase in body weight, egg weight enlarges only about two-thirds as fast. Conversely, as birds decrease in size, egg weight diminishes more slowly—so little birds have relatively heavy eggs.

This promising datum will not, however, explain the kiwi's outsized egg, for the two-thirds slope represents the general standard for all birds. Kiwi eggs are huge compared with the *expected* egg weight for a bird of kiwi body weight along this standard curve.

But the literature of allometrics has also yielded a generality that will, I think, explain the kiwi's massive egg. The two-thirds slope of the egg weight/body weight curve represents a type of allometry technically called interspecific scaling—that is, you plot one point for each species in a related group of organisms and attempt to establish the characteristic change of proportion along a gradient of increasing size. (These curves are popularly called mouse-to-elephant for relationships among mammals—hence my designation hummingbird-to-moa for birds.) Allometricians have established hundreds of interspecific curves for birds and mammals.

Another kind of allometry is called intraspecific scaling. Here you plot one point for each individual among adults of varying body weight within a single species—the Tom Thumb-to-Manute Bol curve for human males, if you will. Since the similarity of these technical terms—interspecific and intraspecific—is so confusing, I shall call them instead among-species (for mouse-to-elephant) and within-species (for Thumb-to-Bol).

As an important generality in allometric studies, within-species curves usually have a substantially lower slope than among-species curves for the same property. For example (and in our best-studied

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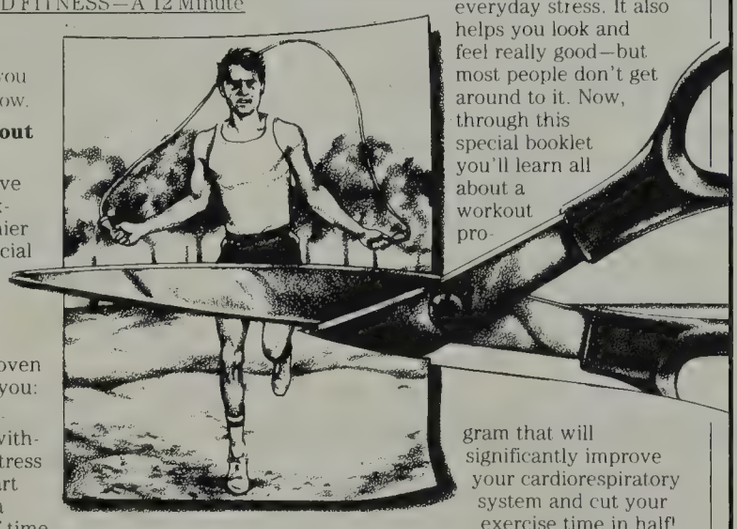

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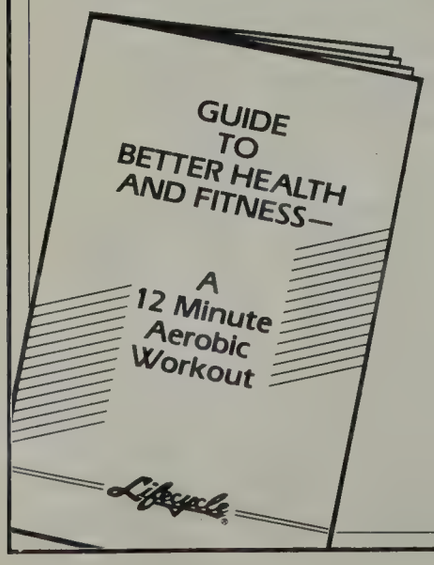

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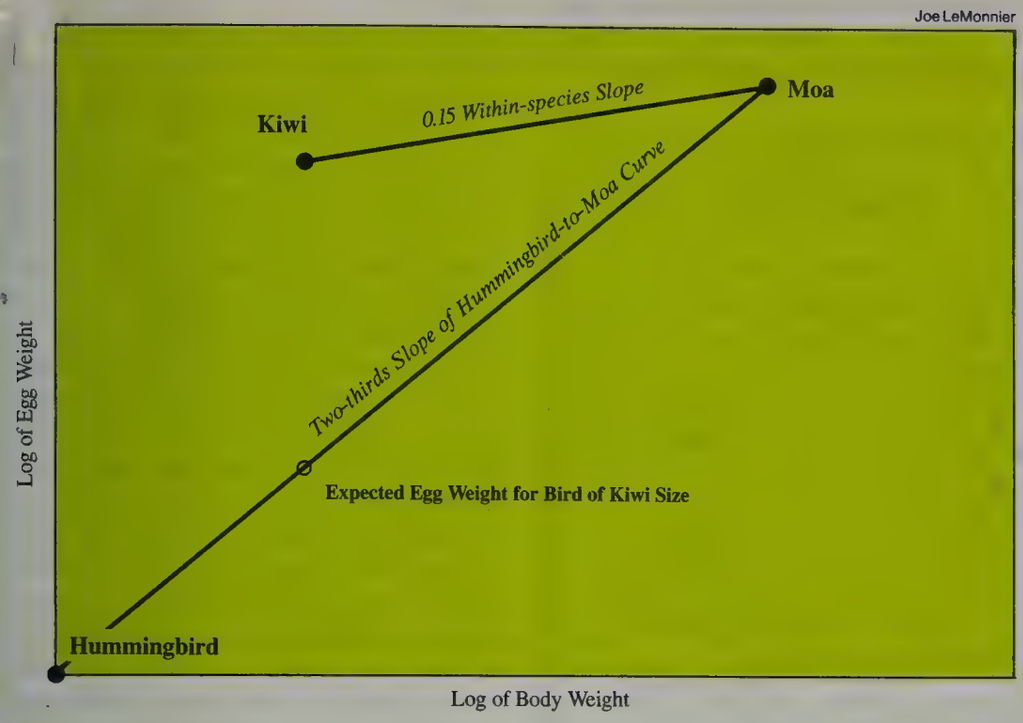
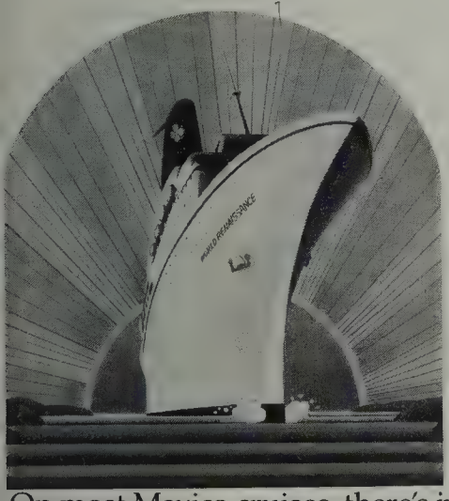


case), the mouse-to-elephant curve for brain weight versus body weight in mammals has a slope of about two-thirds (as does the egg weight/body weight curve for birds). But the within-species curve from small to large adults of a single species, while varying from one group to another, almost always had a much lower slope in the range of 0.2 to 0.4. In other words, while brains increase about two-thirds as fast as bodies among species (implying that large mammals have relatively small brains), brains only increase about one-fifth to two-fifths as fast as bodies when we move from small to large adults within a single mammalian species.

Such a regularity, if it applied to egg weight as well, could resolve the kiwi paradox—if kiwis evolved from larger ancestors. Suppose that kiwi forebears start at moa size. By the hummingbird-to-moa among-species standard, egg size should decrease along the two-thirds slope. But suppose that natural selection is operating to favor small adults within a population. If the within-species curve for egg weight had a slope much lower than two-thirds, then size decrease by continued selection of small adults might produce a new species with outsized eggs well above the two-thirds slope, and therefore well above the expected weight for a bird of this reduced size. (Quantitative arguments like this are always easier to grasp by picture than by words—and a glance at the accompanying figure should resolve any confusion.)

But what is the expected within-species relationship for egg weight? Is it low, as for brain weight, thus affirming my conjecture? I reached for my well-worn copy of Brody's unparalleled compendium and found that for adults of domestic fowl, egg weight increases not two-thirds as fast, but only 15 percent as fast as body weight! (Brody uses this fact to argue that small hens are usually better than large, so long as egg production remains the same—for egg size diminishes very little with a large decrease in body size, and the small loss in



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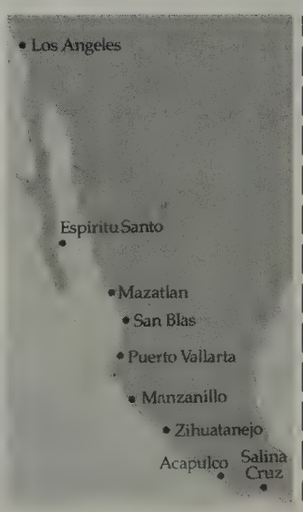

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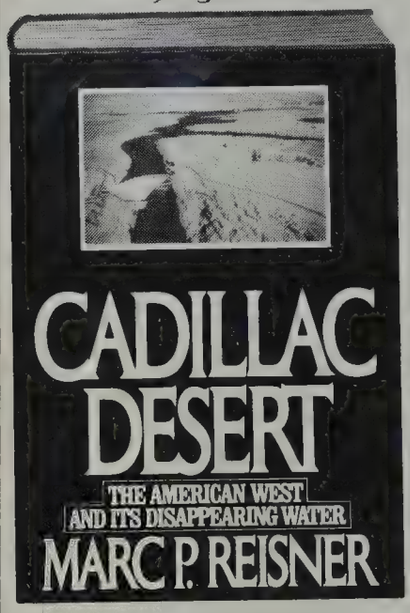

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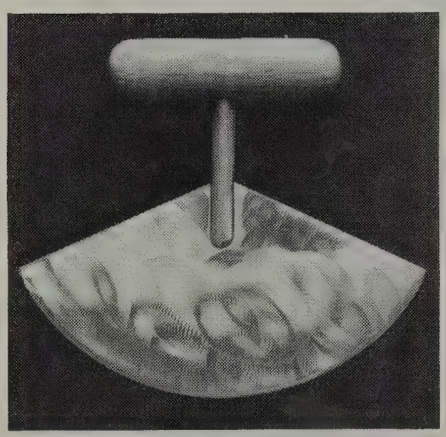

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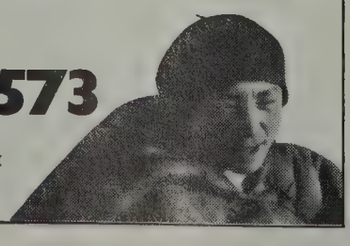

egg volume is more than compensated by large decreases in feeding costs.)

The same argument might apply to kiwis. As a poultryman might choose small hens for minimal decrease in egg size with maximal decline in body weight, natural selection for smaller adults might markedly decrease the average body weight within a species with very little accompanying reduction in egg weight.

I believe that this general argument, applied to kiwis, has three strong points in its favor. First, as stated above, a general finding in allometric studies teaches us that within-species slopes for adults of one species are usually much lower than among-species slopes along mouse-to-elephant curves. This means that any evolution of decreasing size along the within-species curve will lead to a dwarfed descendant with more of the particular item being measured than an average nondwarfed species at the same body weight. Second, we have actual data, for domestic poultry at least, indicating that the within-species curve does have a substantially lower slope than the hummingbird-to-moa curve for our crucial measure of egg weight.

Third, I have studied many cases of dwarfism, and I believe we can state as a general phenomenon—rooted in the first point above—that decline in body size often far outstrips decrease in many particular features. Dwarfs, in several respects, always seem to have much more of certain body parts than related nondwarfed species of the same body size. For example, I once studied tooth size in three species of dwarfed hippos (two fossil and the modern Liberian pygmy)—and found their molar teeth substantially larger, for each of three separate evolutionary events, than expected values for related hoofed mammals at their body size (*American Zoologist*, vol. 15, 1975, pp. 351–62). I suspect that the same phenomenon underlies many orthodontic problems in humans. Although we have grown in body size, our jaws have markedly decreased. But tooth size has not kept up with the drop in jaw size—and most of us can no longer fit our third molars, or wisdom teeth, into our mouths.

As a final example, the talapoin, a dwarfed relative of the rhesus monkey, has the largest relative brain weight among monkeys. Since within-species brain curves have substantially lower slopes than the two-thirds value for the marmoset-to-baboon curve, evolution to smaller size by backing down the within-species curve would yield a dwarf with a far larger brain than an ordinary monkey at the same body size.

Put all this together and a resolution fairly jumps at you for kiwis. Their enormous eggs require no special explanation if kiwis have evolved by marked decrease in size. Kiwi eggs exhibit the weight expected for backing down the within-species curve if natural selection operates only to decrease body size and no other factor intervenes to favor an active reduction in egg size—as we might anticipate in New Zealand, this easy land of no natural predators, where a female might waddle without fear as an enormous egg distended her abdomen during passage down the oviduct.

In this interpretation, if you ask me why kiwi eggs are so large, I reply, "Because kiwis are dwarfed descendants of larger birds, and just followed ordinary principles of scaling in their evolution." This answer differs sharply from the conventional form of evolutionary explanation: "Because these big eggs are good for something now, and natural selection favored them."

My answer will also strike many people as deeply unsatisfactory. It provides a reason rooted in history, pure and simple (with a bit of scaling theory thrown in)—kiwis are as they are because their ancestors were as they were. Don't we want answers that invoke general laws of nature rather than particular contingencies of history?

I would reply that my resolution is quite satisfactory, that evolutionary arguments are often properly resolved by such historical statements, and that we would do well to understand this important and neglected principle of reasoning—for we might save ourselves many a stumble based on trying to apply preferred, but inappropriate, styles of explanation to situations encountered again and again in our daily lives.

To cite just one example where I learned, to my deep chagrin, that a peculiarity of history, rather than a harmonious generality, resolved an old personal puzzle: I had been troubled for a long time by something I didn't understand in the inscription on the Liberty Bell—not losing any sleep to be sure, but troubled nonetheless, for little things count. This national symbol bears, like most bells, an appropriate quotation: "Proclaim liberty throughout all the land unto all the inhabitants thereof" (Lev. 25:10). But the bell also says, "Pass and Stow." I assumed that this too must be a quotation, fit to the purpose of the bell (as selection fits the features of organisms to their needs)—part of the general harmony and chosen plan. I pondered these cryptic words quite a bit because I didn't recognize the source. I consulted Bartlett's and found nothing. I constructed various possibilities: this too will pass, as we stow courage for the coming conflict; oh ye who pass by, remember, they prosper that stow and do not waste; pass the grass and stow the dough. Finally I asked the attendant on duty in Philadelphia. Of course, I should have figured it out, but I was too busy trying to make intrinsic sense of it all. The bell was cast by Messrs. John Pass and John Stow. Pass and Stow is a statement about the particular history of the bell; nothing more. And this, nothing more, was the resolution of my minor trouble.

My odd juxtapositions sometimes cause consternation; some readers might view this particular comparison as outright sacrilege. Some may claim that the only conceivable similarity between kiwi eggs and the Liberty Bell is that both are cracked, but I reply that they stand united in owing their peculiarity and meaning to pathways of history.

Stephen Jay Gould teaches biology, geology, and the history of science at Harvard University.

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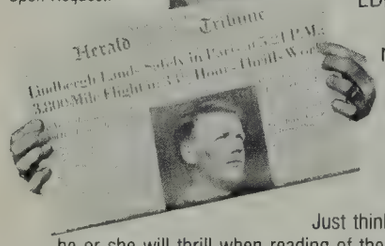

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How Dinosaurs Invented Flowers

One hundred million years ago, plants that didn't flower became fodder

by Robert T. Bakker

Plants evolve all sorts of devices to foil plant eaters: they poison them with deadly alkaloids; they keep them away with thorns and spines; they render plant tissue unchewable by incorporating rock-hard phytoliths into the plant cells or by toughening plant fibers with cellulose; they avoid being eaten by producing new leaves in early spring when plant-eating populations are low. Of course the plant eaters fight back. The evolution of herbivores leads inexorably to better teeth for tearing and crushing the toughest leaves, to more complex digestive systems where enzymes can detoxify plant poisons, to taller shoulders and longer necks to reach higher into the trees, or to lower heads and square muzzles perfect for cropping ground-hugging leaves.

The warfare between plants and herbivores began on land 400 million years ago, when the first algae colonized the bare ground during the Silurian period, and the herbivorous arthropods evolved to follow them. Vertebrate plant eaters on land appeared much later, during the last epochs of the Coal Age, 270 million years ago. Dinosaurs captured the herbivorous niches on land during the Triassic, 200 million years ago, and subsequently maintained their dominance through the entire Jurassic and Cretaceous. But how did dinosaurs coevolve in relation to the plants of their world? Dinosaurs held the roles of large land herbivores for longer than any other vertebrate group, so there must have been a rich history of adaptive attack and counterattack between plant eater and plant. Moreover, herbivorous dinosaurs suffered several episodes of extinction and adaptive revolution that must also have been reflected in contemporary plant systems. And there was a momentous development in the plants during the Mesozoic, for the Jurassic and Cretaceous witnessed the single greatest event in the evolution of the modern system of plants—a turning point that must have changed the life of every plant-munching dinosaur—the appearance of the flowering plants, known collectively as angiosperms.

Today the most conspicuous nonangiosperms are conifers, cycads, ferns, ground pines, and horsetails. But these living Coal Age fossils are outnumbered thirty to one by angiosperm species—from broad-leaved trees, palms, and grasses to food plants—in nearly all habitats. How did flowering plants begin to win this unchallenged hegemony? Whatever the story, dinosaurs must have had a hand in it because the earliest angiosperms sprouted up in a landscape dominated by plant-eating dinosaurs. And they remained the major outside factor for plants all through the first forty million years of the angiosperms' evolution. But for no apparent reason, modern science has ignored the dinosaurs' role in plant evolution nearly completely. Paleobotanists theorize about new insect groups that might have coevolved with the flowers in late Cretaceous times. Mammal paleontologists assert that Cretaceous mammals, no matter how tiny and unimportant, made a major impact on the evolution of angiospermous fruits, nuts, and leaves. But hardly anyone has argued

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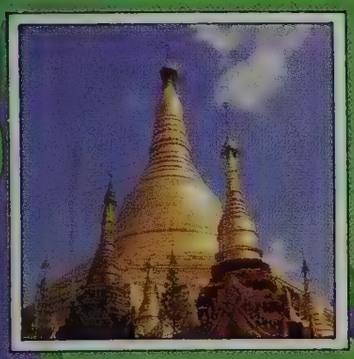

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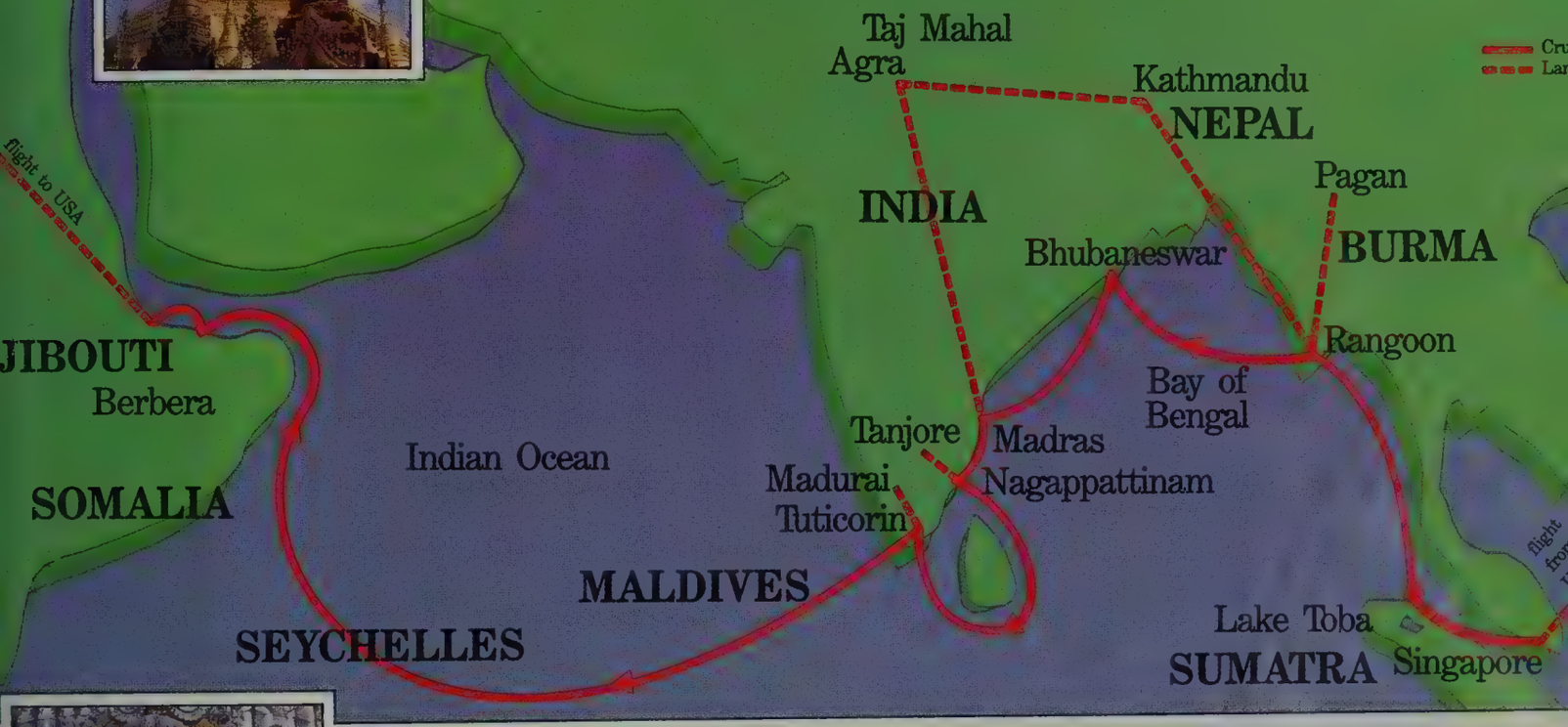

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for the interaction of Cretaceous dinosaurs with the plants that fed them—an extraordinary oversight, considering the dinosaurs were the only herbivores large enough to gobble an entire flowering shrub in one gulp or strong enough to push over an angiospermous tree so as to get at the tender young leaves at the top.

The consistent neglect of the dinosaurs' potential role in the evolution of plants is one of the most pernicious examples of the orthodoxy that relegates the dinosaurs to what amounts to an evolutionary sideshow, a menagerie of irrelevant dead ends that can be ignored so far as any large implications are concerned. Today, large herbivores can change the structure of the flora overnight. Rhinos and elephants can level acacia groves and rapidly crop thickets, converting dense African bushland into open woodland. In the early nineteenth century, the American buffalo kept pushing back the boundary between prairie and forest by its intensive grazing on seedlings. Surely four-ton nodosaurs and three-ton iguanodonts did the same in the early Cretaceous system.

Another bias also works against herbivorous dinosaurs, however. Paleobotanists are a bit chauvinistic about their objects of study. They tend to regard plants as the movers and shakers in evolution, and the plant eaters are consigned to the role of reactors and followers. As one paleobotanist expressed it, "The sun gives energy to plants, and plants give energy to the animals. Therefore, the plants evolve and the animals must coevolve." Stated thus, the assertion is understandable, but misleading. Coevolution works both ways. When plant-eating dinosaurs evolved more effective teeth or fermenting chambers, plants had to adjust to the new weaponry or die. Whichever evolved faster, plant or animal, had the evolutionary initiative. And plant-eating dinosaurs evolved fast, faster than the plants. On average, a species of dinosaur endured two or three million years before becoming extinct and being replaced by a new species. That's a brisk rate of evolutionary turnover, as fast as the mammals'. Such rapid replacement of old adaptive models by new ones guaranteed that the dinosaur plant eaters were always coming up with novel ways to bite, chew, ferment, and digest plant tissue. Mesozoic plants, on the other hand, usually evolved more slowly—the average species of plant lasted eight million years before being replaced by a new one. Since the turnover wasn't as fast, the plants must have been lagging behind the dinosaurs in the evolutionary race.

Herbivorous dinosaurs were in fact the fastest-evolving part of the entire Mesozoic land ecosystem, even faster at adaptive remodeling than their meat-eating relatives. *Tyrannosaurus rex*, the fifty-foot-long Cretaceous killer with seven-

All illustrations by Robert T. Bakker

Nanosaurus, *a four-foot-long omnivore, darts through late Jurassic underbrush, which includes gingkos, cycadeoids, ferns, and ground pines.*

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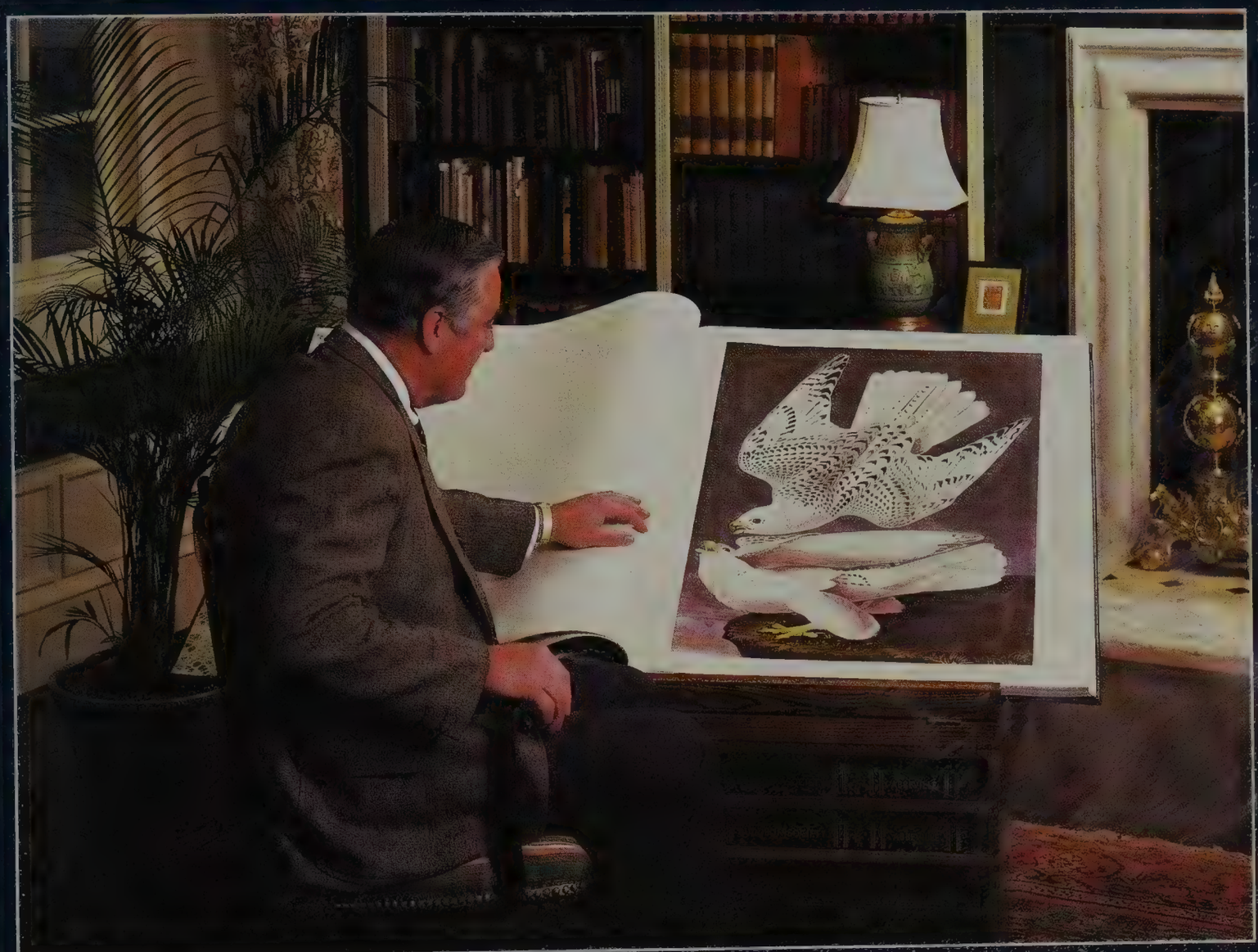

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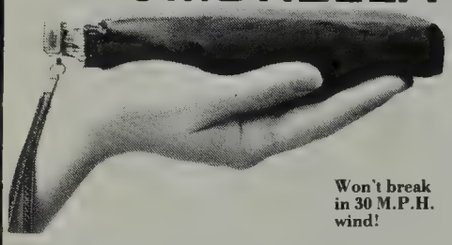

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inch teeth, was really just a sophisticated variation on the basic predator plan first evolved a hundred million years earlier in the late Triassic. Bone by bone, *Tyrannosaurus rex* was fundamentally little different from its ancient Triassic ancestors. But the Cretaceous plant eaters, for example, three-horned *Triceratops*, club-tailed *Ankylosaurus*, broad-beaked *Edmontosaurus*, carried skull and jaw developments that were unknown in the Triassic period.

Among the herbivorous dinosaurs, three grand periods of development are clearly marked.

1. *The Age of Anchisaurs.* The late Triassic and earliest Jurassic, when the long-necked anchisaurs ruled. Anchisaurs were primitive, crude plant eaters by Cretaceous standards. They had simple, iguanalike teeth, suitable for soft leaves only, and their digestive system wasn't much expanded.

2. *The Age of the High Feeders* (stegosaurs and brontosaurs). The middle and late Jurassic, when the spike-tailed stegosaurs joined the gigantic *Diplodocus, Brachiosaurus,* and *Brontosaurus.*

3. *The Age of the Low Feeders.* The Cretaceous, when all the terrestrial habitats were overrun by big-beaked dinosaurs, which fed close to the ground. Each of these types had its own unique approach to cropping the foliage, so each must have made a distinctive impact on the coevolutionary history of plants.

Orthodox dinosaurology has muddied the conceptual waters here by relegating the herbivorous dinosaurs to the swamps, where they are supposed to have gummed nothing but water plants. Now that we have a corrected view of them as dry-land herbivores, it is possible to begin reconstructing a much more accurate context for the Mesozoic evolution of the flowering plants. The first clue to the interaction of dinosaurs and angiosperms can be found in the timing of extinctions. Flowering plants first appeared in the early Cretaceous just *after* the extinctions that occurred at the end of the second grand period (the age of stegosaurs and brontosaurs) and as the replacements for the third grand period (the age of the low feeders) were coming to the fore. This sequence is highly suggestive. When the coalition of stegosaurs and brontosaurs died out at the end of the Jurassic, the plant-eating dinosaurs changed so profoundly that the rules of coevolution must have been reset. Could this dramatic shift from Jurassic-type to Cretaceous-type dinosaurs have opened the way for flowering plants? It's an exciting hypothesis—that the revolution in dinosaur plant eaters caused the single most far-reaching development in the kingdom of land plants. And the evidence suggesting such a cause-and-effect relationship is very good.

Stegosaurus and its close kin were the only common, large, beaked dinosaurs in the late Jurassic. Therefore their feeding

Browsing close to the ground on broad-leaved saplings, a big-beaked Iguanodon *bites off a* Proteaephyllum *leaf. Other early flowering plants include sassafraslike and oaklike species.*

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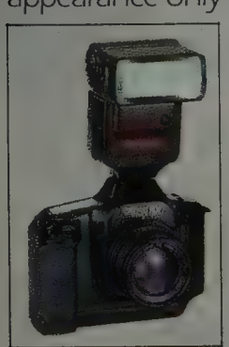

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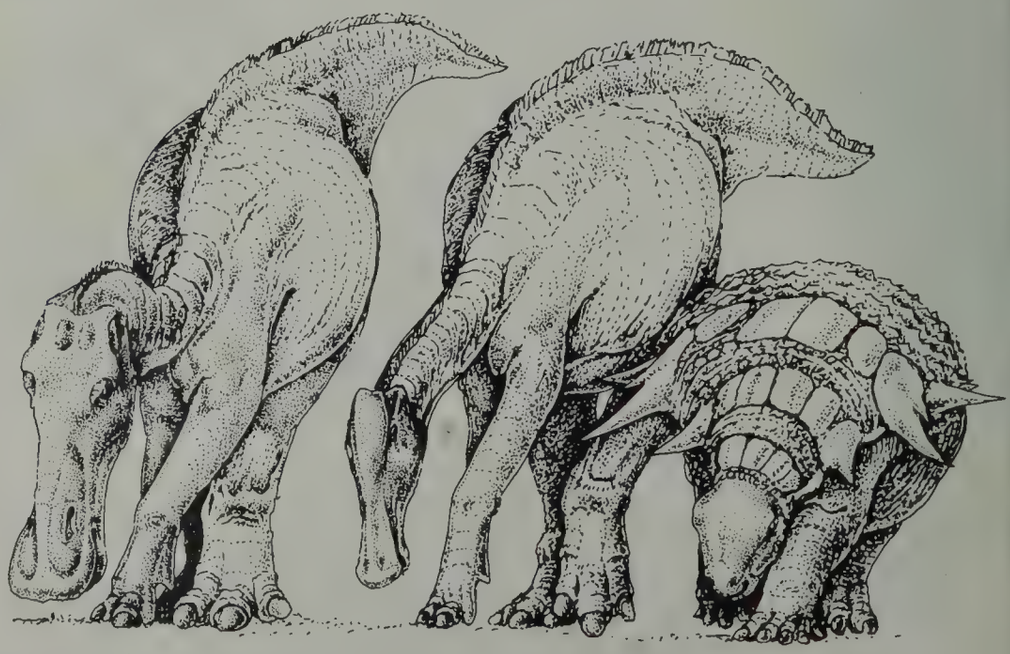
habits must have had a major influence on the evolution of plants. The orthodox restorations depict *Stegosaurus* as an ungainly low cropper, plucking plants from within a few feet of the ground. That is the precise inverse of the truth—*Stegosaurus* wasn't a badly designed low feeder, it was a superbly designed high feeder. The point the usual reconstructions miss completely is that the plan of the stegosaur's body was carefully balanced so the beast could rear up on its hind legs and tail to feed upright, in a tripodal stance. The very tall bony spines at the hips become understandable only in that position. Tall vertebral spines supplied great leverage to the back's muscles and ligaments, so that the entire weight of the trunk could be supported by the hindquarters.

Every one of the giant late Jurassic dinosaurs was a high browser of some sort. *Brachiosaurus*'s tail was too weak for a tripodal posture, but it compensated with its spectacularly long neck, so that even on all fours it could reach up forty feet. *Camarasaurus* was the shortest-necked brontosaur found at the productive Como, Wyoming, site. It could nevertheless stretch up to twenty-five feet with its forelegs on the ground and much higher if it assumed a tripodal stance. Never before or since the late Jurassic has the world witnessed such a profusion of high-feeding plant eaters. This was nothing less than a unique epoch in the history of herbivorous habits. No plant or leaf was safe from a dinosaur's mouth unless it stood more than fifty feet above the ground! Since no flowering plants of any sort existed yet, the principal trees were broad-needled conifers and tall, spiny-fronded cycadeoids. These plants had to be able to protect at least some of their growth through a combination of alkaloid poisons, heavy oils, or spiny branches. As conifers and cycads grow slowly compared to many angiosperms, late Jurassic trees had to guard themselves carefully to prevent the destruction of entire breeding stands.

When the late Jurassic curtain fell and the early Cretaceous began, most of the old, established high croppers died out. The mysterious hand of worldwide disaster swept across the continents, killing off whole families of herbivorous species and thinning the ranks of the surviving clans. Stegosaurs disappeared forever. Hardly a species survived into the Cretaceous. *Diplodocus, Brontosaurus*, and nearly all the other tripodal brontosaurs died out too. Some of *Brachiosaurus*'s relatives survived, but that was an exception to the rule. This tremendous disaster destroyed the high-browsing system permanently; it never recovered. And no Cretaceous dinosaur evolved high-browsing adaptations to replace *Stegosaurus*. A few new brontosaurs evolved—*Alamosaurus*, for instance—but they never came close in number to the glorious days of the late Jurassic.

As the dust settled after these extinctions, the opportunists—evolutionary carpetbaggers—started to move into the devastated ecosystem. New herbivorous groups blossomed into clusters of new species. And nearly all these new Cretaceous herbivores were committed to cropping near ground level. Among the earliest of the newcomers were the big, spike-shouldered nodosaurs. Iguanodonts also evolved early in the Cretaceous, reaching weights of two to three tons and developing broad muzzles for close cropping. Par-



Cretaceous duckbills (left and center) and nodosaurs (right) cropped ground vegetation.

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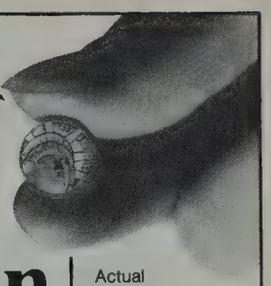

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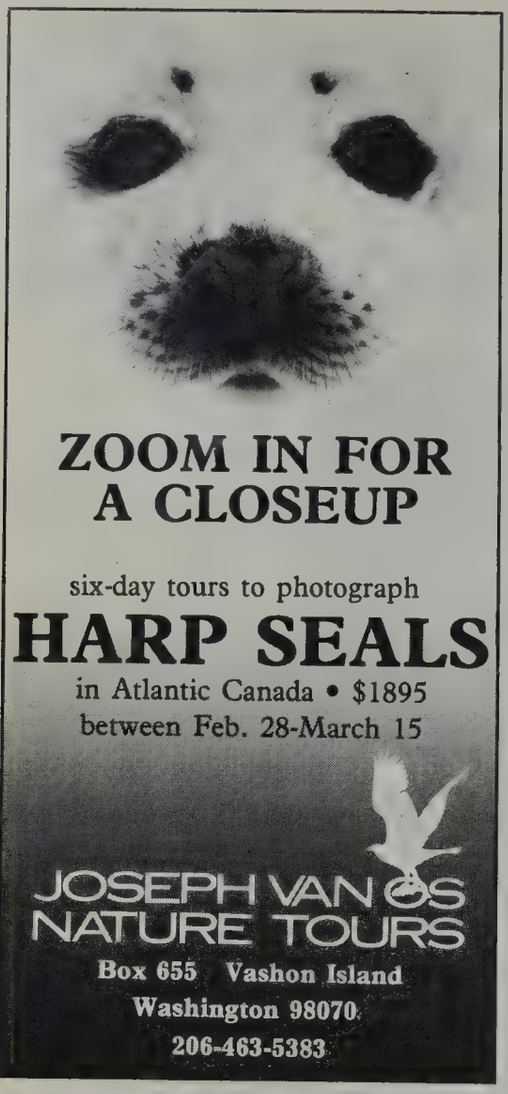
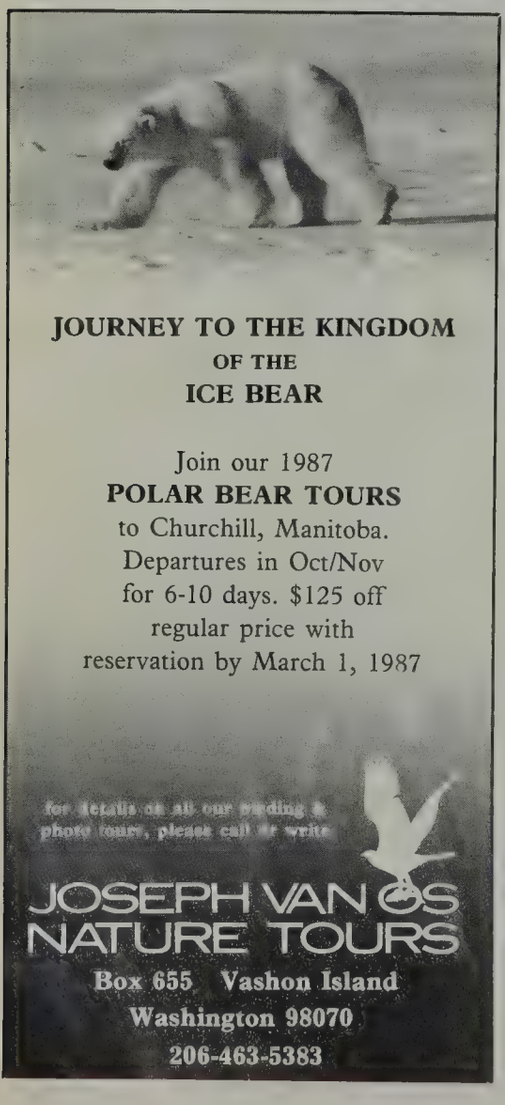




rot dinosaurs emerged shortly after, as did the queer-looking domeheads, both groups with their backbones curved to bring their snouts close to the ground. More and more low feeders appeared as the Cretaceous continued—the wide-snouted ankylosaurs, the large- and small-horned dinosaurs, and myriad duckbills.

This was an unprecedented alteration in the nature of plant eating. In place of the late Jurassic's tall browsers, the Cretaceous herbivores concentrated on munching close to the ground. Low shrubs and seedlings now faced a threat from herbivores magnified many times compared with the conditions prevalent during the Jurassic. In this ecological context the very first flowering plants appeared on the earth's surface. How did the Ur-angiosperms react to all this munching close to the ground? One ideal adaptive strategy for a low woody shrub or seedling would be to grow as fast as possible to achieve a height where the low browsers could not threaten it. Early angiosperms could do that—their basic reproductive equipment gave them a fast-growing edge over many contemporaneous plants. A second approach would be a "dicey" strategy—scatter sufficient seeds onto an overgrazed patch of bare soil to produce a clump of shrubs quickly, and thus spread another generation of seeds before the herbivores returned and once again mowed everything to the ground. Early angiosperms could do that too—their seeds and flowers allowed them to spread more quickly than conifers or other nonflowering plants.

Intense low cropping placed a premium on any and all plant adaptations for fast spreading, fast growing, and fast reproduction. And early angiosperms performed exactly these biological functions especially well. From this, a quite plausible scenario emerges: low feeding Cretaceous dinosaurs opened the way for the initial waves of angiosperms. Conifers, cycadeoids, and other nonangiosperms were probably far less adaptive for handling the assaults of new Cretaceous herbivores. Anywhere the plant eaters thinned out the conifer groves and cycadeoid thickets, an opportunity for species of flowering plants to win a foothold in the habitat was created. Early angiosperms were probably cropped just as severely as their neighbors, but their basic adaptations permitted them to continue growing and reproducing in the face of the intense mowing action of the dinosaurs.

Footholds are crucial for major adaptive revolutions. Any new group finds breaking into an ecosystem already full of old, established groups difficult. Conifers were highly adaptive old-timers in early Cretaceous times—the conifers had indeed begun long before the first dinosaur evolved in the Triassic. Cycadeoids were old-timers too, already diverse in the early Jurassic period. When angiosperms first evolved, they were confronted with meadows, woodlands, and forests full of long-lived, highly refined plants. Early angiosperms possessed adaptations that were new and potentially revolutionary. But they needed some edge—an opening for breaking out of the confines imposed by the older groups—to start proliferating species. Herbivorous dinosaurs gave them that initial break.

Flowering plants and low-feeding beaked dinosaurs must have coevolved in a mutually beneficial way. As more and more new kinds of Cretaceous beaked dinosaurs entered their ecosystems, more and more angiosperm families evolved. From the meek beginning of a few early Cretaceous species, the angiosperms grew into a mighty clan by the late Cretaceous, boasting more species than conifers and cycadeoids combined. When the Cretaceous ended, massive extinctions again swept through the terrestrial habitats. Cycadeoids disappeared, but angiosperms not only survived, they increased their share of the species count in epoch after epoch down to the present day.

Modern angiosperms no longer depend upon intense low feeding for their advantage over conifers and ferns. They now contain hundreds of specializations for every habitat from tall climax forests to swamps and deserts, windswept mountain meadows, and bare rock faces. But in those first critical years of their evolutionary history, the angiosperms were struggling newcomers. Square snouts and pincerlike beaks helped the flowering plants beat the floral competition and establish the angiosperms as the fastest-evolving plant group. There was, of course, no plan in this. *Stegosaurus* didn't die out purposely to permit its low-cropping cousins to take over and make the world fit for flowers. Wide-mouthed ankylosaurs didn't plan to munch down the competition. It was all serendipitous. Nonetheless, because of the way they suffered extinction and then rebuilt their herbivorous groups, the dinosaurs played a central role in one of the grandest dramas of the flora. In their way, dinosaurs invented flowers. Without them, perhaps our modern world would yet be as dull green and monotonous as was the Jurassic flora.

Paleontologist, author, and artist, Robert T. Bakker is adjunct curator at the University Museum, University of Colorado, Boulder.

Male goats' horns are useful both as weapons and, as here, back scratchers.
Laurie Campbell; Natural History Photographic Agency

Rhum Deal for Goats

Cold, mountainous, wet, and buffeted by storms, the Isle of Rhum may not be a tropical paradise, but for some 200 feral goats, it's home

by Robin Dunbar

To the Vikings, it was Röm öe, the "wide island," the one you could not miss as you passed down the treacherous channel between the Scottish mainland and the Outer Hebrides on your way to raid in Galloway and Ireland. Today, we still call it the Isle of Rhum. Wettest and most mountainous of the islands off the northwest coast of Scotland, Rhum boasts a long history. The very names of its hills resonate with Viking memories—names like Trollaval ("mountain of the trolls") speak to us across the centuries of the uncertainties of life a thousand years ago.

The Vikings renounced their claim to the Hebrides in 1266, and the ownership of islands like Rhum reverted to the native Scots chieftains. Crofters (smallholders) continued to eke out a living from the thin soil, perpetually at the mercy of the unpredictable elements, and for a few hundred years, supported by the all-important clan system, they managed to survive. But by the 1820s things had reached a crisis point in the highlands and islands of Scotland. Following a succession of disastrous harvests, the crofters were forced to fall back on the traditional charity of their clan chiefs. But clan loyalties were no longer what they once had been. The lure of high society in London and Edinburgh had broken the ancient ties between chief and clansman, and few chiefs were prepared to sustain a prolonged drain on their family fortunes. Sooner or later, most of the chiefs evicted their tenants and turned their estates over to sheep, the new economic miracle of the time.

The island of Rhum was no exception, though its landlord, MacLean of Coll, was more generous than many of his contemporaries. He gave his tenants on Rhum a year's notice to quit and offered to pay their passage across the Atlantic to Cape Breton in Canada. Finally, in 1828, the 450 inhabitants set sail, leaving behind only the ghosts of their centuries-old occupation—the crumbling drystone walls of the low, turf-roofed huts in which they lived, the traces of the terraces where they grew their crops, and their goats.

More than a century and a half later, the descendants of those goats still live on Rhum. Long after a collapse in the price of wool forced MacLean to abandon his sheep scheme and sell the island, the goats continue to roam the great sea cliffs along the island's windswept Atlantic coast. They have survived both Victorian and Edwardian sport hunters and, more recently, efforts to eradicate them altogether for fear that they threatened the island's fragile ecology.

But even for animals as tenacious as goats, life on Rhum remains precarious. The acidic, waterlogged soils support a nutritionally unexciting mix of plants, dominated by heather, sedge, and moss. On this fare, the goats must endure a climate that drenches them with interminable drizzles and sea fogs and then chills them to the bone with gales that once drove Viking adventurers to shelter in the island's rocky bays. The cost bears heavily on the goats. Goats are renowned for a fertility that, under optimum conditions, can run to twins twice a year. But the goats of Rhum are hard pressed to manage even a single kid each year. And half of all kids succumb to the severity of the climate before their first birthday. With such low birth rates and such high death rates, the Rhum population can only just hold its own, building itself up a little in mild years only to be cut back again when a poor summer or a particularly harsh winter

Laurie Campbell; Natural History Photographic Agency

The biggest males do most of the mating. Below: When rival suitors are closely matched in size, they may jostle for access to the female, sniffing her rump to determine her sexual state. If she is receptive, fierce fights may break out. Right: A large male, five years old and in his prime, stands guard over his prize. At his left, three younger males look on (from left to right, they are about six months, one year, and three years old). Although too small to challenge the older male, these goats are intensely interested in the proceedings and might try to sneak a mating if the opportunity arises.

Robin Dunbar

proves to be too much for the weaker animals to endure.

Survival for the Rhum goats depends on finding shelter during the long winter nights, when windchill lowers the effective temperature to well below freezing. During the day, the animals forage on the great sea cliffs that rise as much as a thousand feet above the rocky shore. But as the sun drops toward the indistinct blur where sky merges into sea, they head pell-mell back down to the seashore to spend the night in caves gouged out of the sandstone by the sea. In winter, nighttime temperatures in the caves are as much as nine degrees higher than those at the top of the cliffs. Snug in their caves, the goats doze fitfully, huddled together for warmth, their yellow slit-eyes staring unblinking into the gloom.

The social life of goats revolves around the nanny groups, each of which consists of an old female and her daughters and granddaughters, three or four generations of females sharing a range inherited from the matriarchs before them. The females' attachment to the range, and thus to their group, is strong; individuals moved elsewhere often try to find their way back, even across many miles of wilderness. Such loyalty is an ancient trait, shared by at least two other members of the goat family (namely, the ibex species of Europe and the Horn of Africa), and it undoubtedly can be an important element in the females' antipredator strategy. Safe as goats on steep hillsides may be from some predators, they can all too easily be knocked off balance by large birds of prey harassing them on cliffs (or, more recently, by humans hunting with rifles). Where one misstep can lead to oblivion a thousand feet below, vigilance is essential. By forming groups, the females can take turns keeping watch, so that at least one wary eye is turned skyward while the other goats are free to feed.

Rhum's male goats are much more adventurous, often moving over very large areas. In winter, they settle on small ranges interspersed among the female groups, often choosing a different range in each successive winter. For much of the year, life in the bachelor groups is sedate, a gentle round of feeding and sleeping on the crags. Then in mid-August, the world suddenly erupts into the chaos of the rut, a month-long period of unremitting devotion to just one activity: the business of mating. Everything else becomes of minor importance. Health, safety, friendships of the winter months—all are forgotten.

"The he-goat," observed the author of the twelfth-century *Book of Beasts*, "is a lascivious and butting beast who is always burning for coition. His eyes are narrowed because he is so lusty." As the female comes into season, the males gather round, jostling for position. Although they begin to take an interest in the rut in their first year, the males are really too small to be more than onlookers until the age of three. At four and five, they are at their peak. Fights break out with a fervor unsurpassed among mammals. The goats engage in a rapid series of head butts, horn crashing against horn until one or the other of the antagonists backs down.

Inevitably, it is the biggest and heaviest males that get to tend to the females most often. These males all but forgo feeding,

for to take time out to eat would be to surrender the prize to a rival. The males lose weight rapidly, and by the end of the mating season, they are exhausted. In the rapidly shortening autumn days, when forage is already declining in both quality and quantity, the males are unable to recoup their losses. Many die in the ensuing months. Even for males that survive the rigors of the breeding season, the strain of the competition takes its toll. By six, males are no longer able to compete effectively; by seven, most of them are dead.

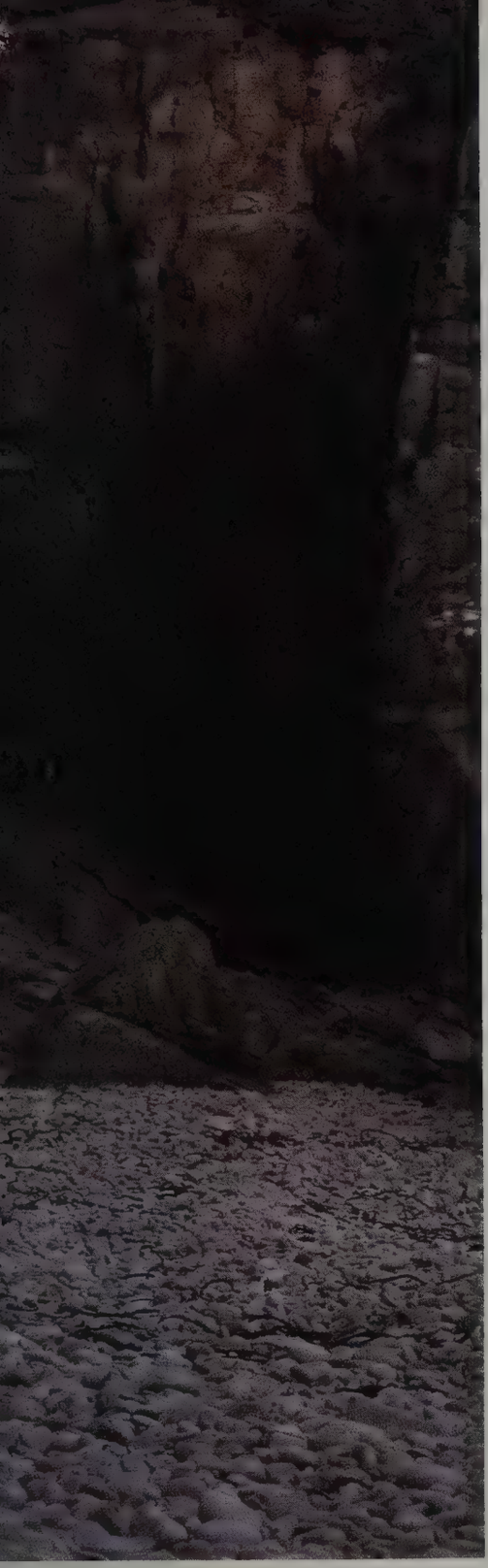
Rutting males are so single-minded in their pursuit of females that they often get themselves into situations from which they cannot easily extricate themselves. I once watched a group of four billies harassing a young female. Alternately crowding her as she tried to feed and sparring among themselves, the males were causing her a good deal of trouble by their attentions. Finally, she made a particularly determined bid to escape by scrambling up a nearly vertical cliff several hundred feet high. She managed easily, leaping nimbly from one narrow ledge to another and then up a chimney in the rock face. Without a moment's hesitation, the four males followed her up, one after the other. But they were not so agile and soon got stuck on a narrow ledge about halfway up. There they came to a standstill, peering around with evident perplexity, unable to move either forward or backward, the four of them jammed together on a ledge that would barely do for one. After twenty minutes, the leading male, for whom the scent of victory was no doubt greater, managed to scramble up the remaining hundred feet to join the female browsing peacefully above. But the other three, with the battle lost and the prize gone, had less incentive to risk a fatal fall. They stayed where they were, shuffling backward and forward in an effort to maintain their balance, until dusk obscured them from my view. When I found them again the next morning, they were grazing contentedly on the beach, for all the world as though nothing had hap-

pened. How they managed to get down is a mystery.

A male goat's problem, to be fair, is a serious one. Unlike the females, males play no part in caring for their offspring. The billy goat's reproductive effort consists entirely of attempting to mate with as many females as he can during his lifetime; this is the most effective way for him to pass on his genes to future generations. Yet because of the shortness of the breeding season and the ferocity of the fighting, he must spend the greater part of his life on the sidelines, too young or too old to fight, while the males in their short-lived prime exercise a near unchallengeable monopoly over the females.

But there are ways a wily male can overcome these natural disadvantages, at least occasionally. One is a consequence of big males being less agile than small ones. Although big males can easily guard a female while she is standing still, the moment she runs to escape the fighting going on around her, the smaller males come into their own. Faster on the turn and more nimble on the rocks, they can keep up with the female's twists and turns more easily than the big males with their massive horns and greater bulk. So at the critical moment when the female is ready to mate, small males may get an unexpected opportunity to mate practically beneath the big males' noses.

Furthermore, the females do not all come into heat at once. Each is in estrus for about a day at a time, and the timing of the various females' estrous periods is quite random over the month or so of the rut. Consequently, the males have no idea where the next estrous female is likely to be. She might be in the same group of nannies as the female they are currently tending or in a nanny group several miles away along the cliffs. This unpredictability makes it worth a male's while to leave the cluster gathered around one female and go in search of another that has not yet attracted attention. Having found one, he may gain half a day's uninterrupted courtship before the others catch on and



Rhum's goats spend the freezing winter nights huddled in caves gouged out of the sandstone cliffs by the sea. Entrance to the large cave, known as Wreck Bay Cave, left, is blocked at high tide, so the goats must time their comings and goings accordingly. A young female, below, probably little more than two years old, suckles her first offspring. Despite its nanny's assiduous care, the kid has only a 50 percent chance of surviving to its first birthday.

Both photographs by Laurie Campbell; Natural History Photographic Agency

join him. Mating groups are consequently unstable, with young and old males constantly joining and leaving. The males move at a phenomenal pace once they leave a group, often searching an area of several square miles at a flat-out run.

Wild goats are usually nervous animals, fleeing at the merest hint of danger, but during the rut, males are so preoccupied that they will approach anything providing that there is a slim chance it might be a female. I once had this impressed on me with particular force when I was watching a group of about fifteen goats from a headland on one side of a small bay. They were about a quarter of a mile away, on the sea cliffs opposite where I sat. Between us, a small river cut a deep gorge that opened out to form the bay. On my side, the cliff was very steep, about four hundred feet of overhanging rock face rising to a steeply curving grassy slope. After going down the slope as far as I dared, I nestled into the grassy bank where I was sheltered from the wind in a small nook warmed by the sun's rays. It was an idyllic spot that I often used as an observation point from which to watch goats.

I had, I suppose, been there for almost an hour watching the goings-on across the bay through my telescope, when one of the bigger males left the group and headed rapidly inland. Since he was obviously departing in search of a less embattled female, I took little notice of him once he disappeared from my view. But a few moments later, I was startled by an indignant snort. There he stood, a mere five yards away, hesitantly stamping a forefoot and eyeing me with a mixture of uncertainty and barely disguised intent. He had evidently spied my shape nestled into the hillside across the bay and come rushing over to investigate.

At first, I was amused by his mistake and evident confusion. But the longer he stood there, his great horns swaying ominously as he tested the air in my direction, the less amused I became. My comfortable little nook began to seem an altogether perilous place. With a crazed hegoat between me and safety, my only escape seemed to be down an overhanging rock face that even goats balked at. I began to curse my stupidity in the pursuit of science, oblivious to the irony of the situation: sex and science—how irrelevant the difference when single-mindedness of purpose traps the unwary. Further deliberation was fortunately forestalled by the goat's decision that I was apparently beneath his interest. With just a hint of affronted dignity in the tilt of his head, he turned and trotted back to his companions on the far side of the bay. I never did use that observation point again.

For the nanny, mating is a minor inconvenience; kidding is much the more trying time. She takes herself off to a secluded place along the rocky shorelines to give birth. There she remains with her kid for about two weeks before she leaves it and rejoins her group on the upper reaches of the cliff. The kid remains in its hiding place for up to a month, until it is able to follow its dam across the rugged landscape without falling. Throughout this time, she visits it at intervals to nurse it.

The nanny assiduously guards her kid and keeps a lookout for predators, just as her ancestors did for millennia before her.

Dietary opportunists, goats will eat almost anything, although given a choice, they prefer to browse on bushes and shrubs. On Rhum, goats forage by day on the rocky cliffs. When heather, sedges, and grasses are in short supply, even seaweed and lichens are not disdained.

Both photographs by Laurie Campbell; Natural History Photographic Agency

Only now, there are no predators on Rhum. Wolf and lynx have long since vanished from the British Isles. In more recent times, the goats would have been harried by the massive golden eagles and the great white-tailed sea eagles that cruised the Hebrides in search of prey. But only one pair of golden eagles now breeds on the island, and sea eagles disappeared some decades ago, though they are now being reintroduced to Rhum from Scandinavia. Whether these birds of prey will reproduce successfully on Rhum and once again prove a menace to the goats remains to be seen.

The female's problem is not an enviable one. To give her kid the best chance of reaching adulthood, she has to insure that it is as big as possible by the time winter rolls around again, when the kid will have to fend for itself. This means giving birth early in the year. But if born too early, the kid has to cope with the winter cold while still very small; the smaller the kid, the more rapidly it loses heat.

For the first two months of its life, the young goat feeds exclusively on its mother's milk. To meet her kid's energy needs, the mother goat must be able to find enough good forage for herself. This, too, sets limits on when she can give birth. In the temperate latitudes of Rhum, the main growing season for plants is restricted to a brief two months in the spring. Thereafter, the quantity and quality of the browse decline steadily. To make the most of the growing season, the mother goat needs to produce her kid not later than mid-March. So, she gives birth in February, sometimes even as early as January, when the winter weather is at its worst. Inevitably, large numbers of kids are lost. Four in every ten fail to make it through to the summer, and another one will die before its first birthday.

On Rhum, a nanny can expect an active reproductive life of, at most, eight years, during each of which she will produce a single kid, which will stand only a 50 percent chance of surviving to maturity. That means just four surviving offspring at the end of her lifetime.

By comparison, goats in the tropics have an easy time. They kid throughout the year with little sign of marked seasonality. Small wonder, then, that goats on tropical islands have often multiplied out of all proportion. With an ability to twin twice each year, the average nanny can produce forty-eight offspring during a typical reproductive life of twelve years. Just how productive goats can be under benign environmental conditions can be illustrated by the fate of the population on the Galápagos Islands off the coast of South America. In 1959, three goats were released on Isla Pinta. Ten years later they had become so prolific that they were causing serious damage to the habitat on the island, and a concerted attempt to eradicate them was instituted. During control operations between 1971 and 1977, 40,000 goats were shot, and even then it was thought that a few thousand still survived on the island.

Goats are the archetypal survivors. Evolved to exploit a niche in the marginal habitats of the Old World's mountain massifs, they are adapted to making the most of each and every break that nature offers them. Independent, able to subsist in habitats that have next to nothing to offer, and capable of responding with an impressive burst of reproduction the moment environmental conditions take a turn for the better, the wild goat was a gift for those entrepreneurial nomads of the Near East who first domesticated it some 30,000 years ago.

In more recent times, pirates and mariners made good use of goats, too, dropping them off on uninhabited islands in the hope that they would multiply and turn into a self-sustaining supply of fresh meat. They served their purpose well. Many a shipwrecked mariner, from the fictional Robinson Crusoe to the real-life English privateer Sir William Dampier, had reason to be grateful for the presence of goats on otherwise deserted oceanic islands.

Unluckily for the goats, they did only too well in some places. Growing at unprecedented rates, some populations made short shrift of the delicate ecosystems on isolated islands whose vegetation had not evolved with large mammalian herbivores. New Zealand and the Hawaiian Islands suffered especially badly, and as a result, feral and introduced goats everywhere gained an undeservedly bad reputation. But not every island has turned out to be a goats' paradise. In places like Rhum, the goats found themselves faced with just the kind of harsh climate that their ancestors had evolved to cope with. If anything, their tenaciousness and ability to survive in such circumstances deserve our respect. □

The sea anemone Metridium senile, *photographed off the Massachusetts coast, extends a fighting tentacle far beyond the surrounding feeding tentacles. These elongated tentacles reach out to inflict damage on neighboring anemones, which will often move to escape injury.*

Kenneth P. Sebens

The Anemone Below

Colorful contenders battle for territory amidst tidal rock and reef

by Kenneth P. Sebens

A mile off the northwest tip of Washington State's Olympic Peninsula lies Tatoosh Island, a collection of small rocky islets separated by narrow draws that are protected from the ocean's thundering swells. Snorkeling here during high tide, swimming seaward through these draws, I saw giant green sea anemones, *Anthopleura xanthogrammica*, emerge from closed low-tide postures and unfurl sunbursts of brilliant blue-green tentacles.

With the first waves of the incoming tide, the anemones relax the muscles that cover their tentacles. Slowly, the tentacles unfold and inflate, more than doubling the animal's size. When fully expanded, water is pumped in through the mouth, filling the tentacles and body. This hydrostatic skeleton holds the tentacles erect even during the rush of water and foam from breaking waves. Once the tide rises a few feet, the anemones move only slightly with each wave surge. When I tossed a small mussel onto an anemone's tentacles, this normally slow-moving creature reacted instantly, wrapping around the mussel in a second or two. In less than a minute, the prey was swallowed and the tentacles were again at the ready.

Often compared to flowers, sea anemones are voracious carnivores that grasp, paralyze, and devour swimming prey, usually crustaceans and small fish, as well as mussels and barnacles dislodged by waves. They are also fierce defenders of their territories, using specialized tentaclelike organs to battle neighboring anemones on the rocky shores and crowded coral reefs they colonize. It was this agonistic behavior that I studied off Tatoosh Island's shores and which I then compared with the fighting practices of anemones on other rocky shores and reefs.

Anemones are members of the phylum Cnidaria, which also includes hydroids, jellyfish, sea pens, corals, gorgonians, and many other common forms in both temperate and tropical seas. Their closest relatives are the corals. A sea anemone is very similar in structure to a single polyp of a reef-building coral but lacks the coral's hard calcium carbonate skeleton. The evolutionary loss of the skeleton gave anemones the ability to move easily. Cnidarian behavior is coordinated by simple nerve nets: one in the inner cell layer (endoderm, or gastrodermis); the other in the outer cell layer (ectoderm, or epidermis), with some cross-communication between. There is no central nervous system, no brain, not even a dense concentration of nerve cells that can be thought of as a center of coordination. Cnidarians, including sea anemones, are examples of animals with "simple" nervous systems, yet recent research continues to find them capable of increasingly complicated behaviors.

All cnidarians capture their prey by firing thousands of microscopic "harpoons" from structures called nematocysts. One type of nematocyst penetrates the prey's flesh and anchors itself with barbs; a similar capsule, the spirocyst, fires sticky threads that adhere to the hard outer skeletons of mollusks or crustaceans. Tentacles studded with these nematocyst and spirocyst capsules transfer captured prey to the anemone's mouth, where they are then ingested into the coelenteron, the central cavity that is the animal's equivalent of a gut. Certain anemone species are zooplankton feeders; others, especially the large anemones of temperate rocky shores, depend on wave action to dislodge mussels, snails, sea urchins, and other invertebrates, which then tumble into the grasp of their tentacles.

Marine animals and plants that live on rock surfaces grow and reproduce at a rate that rapidly fills the available space. Surfaces for attachment are a limited resource and competition for that resource is inevitable. A brief look at any tide pool or coral reef illustrates this fact. Every surface is filled with some sort of living creature, and many different species are present, each individual in contact with several others. It is at such contact points that aggression and defense of space occur, just as they do in territorial birds, mammals, or coral reef fish.

The simplest form of aggressive competition for space is overgrowth of one species by another. A successful defense is to build a wall of tissue or skeletal material that can stop the aggressor or to do something equally harmful in response. Judith

Lang, working on reef corals in Jamaica, found that some coral species have just such a defense. If a coral of one species begins to grow over a neighbor's edge, the defending coral can throw its mesenterial filaments onto the intruder. These thread-like organs normally constitute the coral's digestive system within the coelenteron, but during aggressive encounters the filaments can be ejected out of the mouth and onto an adjacent coral. There, they begin to digest that coral's polyps, effectively stopping its growth. Some corals also develop sweeper tentacles, which, when developed and inflated in response to contact by a neighboring coral, can be more than ten times as long as the feeding tentacles. Sweeper tentacles contain dense fields of nematocysts that destroy coral tissue that they contact. Once defeated by the mesenterial filaments of a neighbor, certain corals can develop sweeper tentacles in response, then come back to win the long-term encounter.

Sea anemones, moving along the reefs or rock channels, commonly contact other anemones and corals. The giant green anemones of the North American west coast move frequently when young. In a few weeks their movements, imperceptible to the human eye, can carry them across several yards of rock in search of currents and temperatures that will increase the likelihood of surviving and finding food. Larvae may settle far from their eventual adult home. Along the coast of Washington State, anemone larvae settle in intertidal beds of the large mussel *Mytilus californianus*—a safe haven with plentiful food in the crevices between mussels. There the small anemones grow and eventually migrate downward to the low intertidal pools and surge channels. This is a perfect position from which to capture mussels torn loose by wave action.

Lisbeth Francis, working on the California coast, and A. Bonnin, conducting research independently in France, noticed that certain anemones inflate saclike vesicles below the tentacles when they come into contact with other anemones. These vesicles, technically termed acrorhagi, lose their tips when they contact other anemones. These pieces of the vesicles stick to the body or tentacles of other anemones; large specialized "homotrichous" nematocysts in the tips inject chemical compounds that cause tissue death (necrosis). When the tentacles of two anemones come into contact there is an attack and counterattack. The tentacles are pulled back out of the way and the large white acrorhagi are raised and

At left, the tentacle crowns of two Anthopleura elegantissima *tangle. The anemone on the right has begun to inflate its acrorhagi—the white spheres between the pink-tipped tentacles. As the battle ensues, both anemones will retract their tentacles, fully extend the acrorhagi, and then bend to make contact. Below: The contact zone between two colonies of the reef-building coral* Montastrea cavernosa. *Individuals of both colonies have developed fighting tentacles with batteries of white nematocysts on their tips.*
Ann Wertheim

Kenneth P. Sebens

brought down in graceful arcs. The loser, usually the smaller individual, eventually ceases its counterattack, pulls in both tentacles and acrorhagi, and glides slowly away from the zone of contact.

Lisbeth Francis found that an anemone could discern whether it had just contacted an anemone of its own clone (identical genetic makeup, or genotype) or an anemone of another clone. The mechanism that makes anemones so discriminating is still unknown, but preliminary research indicates that any piece of intact tissue of a different genotype will stimulate the entire agonistic sequence. No chemical fraction of that tissue or surface mucus will do the same, however. This means that the recognition of self (identical genotype, whether connected or not) versus nonself (different genotype) may be similar to the immune reactions of humans and other mammals in which the body's defenses must recognize foreign, often dangerous, material. Recognition is accomplished by matching configurations of proteins on the cell membrane surfaces. Each individual has a slightly different pattern of those molecules just as each person's fingerprints are unique.

Many anemone species have the ability to divide in half or to pinch pieces off their base and thus form new anemones without sexual reproduction. All such species also reproduce sexually at the appropriate time of year. *Anthopleura elegantissima*, the west coast aggregating anemone, divides itself in half usually once a year, producing two individuals with each division. These "daughter" anemones remain close together and form aggregations of hundreds of individual polyps. Divided anemones are not attached and are thus physiologically independent, but genetically they are true clones of a single original individual.

Borders between aggregations of this small green anemone are battle zones, where genetically distinct clones contact one another. Lisbeth Francis found that anemones along these borders develop more and larger acrorhagi in response to frequent contact with anemones of other clones than do individuals at the center of the aggregation. Thus edge individuals become specialized as "soldiers," while individuals in the center never receive this stimulus and more of their available energy goes to growth and reproduction, instead of being used to build weapons. This division of labor is reminiscent of the differentiation of social insects into specialized castes.

Aggregating clonal anemones are not the only anemones that fight for space; solitary anemones also fight even when open space is apparently available nearby. This behavior may reduce crowding in the local population; fewer anemones increase the probability of each capturing prey.

Observing the giant green anemones as the tide was rising showed that they began their aggressive behavior when wave surge caused nearby anemones' tentacles to brush each other. The next fifteen to thirty minutes provided a spectacular display as a few large individuals inflated their acrorhagi and raised them high above nearby anemones. A slow contraction on one side of an anemone's body brought the acrorhagi down onto another's tentacles and body, causing that anemone to jerk away, then contract. During my research on Tatoosh Island I removed anemones and brought them into contact with their former neighbors or with anemones several yards away. Anemones battled all newcomers but tolerated their present neighbors even in a new position. Somehow, these anemones learn to recognize established bordering individuals and not waste time fighting them.

Acrorhagi are found in only one family of anemones. Some other anemones have tentacles, termed catch tentacles or fighting tentacles, similar to the sweeper tentacles of corals and use them in identical fashion. The fighting tentacles reach far beyond each anemone's own tentacle crown and seem to search out other clones in a radius around themselves. Once an anemone of another clone is touched, the tentacle tip is released and sticks to that anemone just as do the tips of acrorhagi. Nematocysts then inject toxins that destroy the tissues. Anemones thus damaged move away, relinquishing their space. Jennifer Purcell and Christopher Kitting

Kenneth P. Sebens

In a tide pool on Tatoosh Island, below, the tentacle crowns of the giant green sea anemone, Anthopleura xanthogrammica, *keep mostly out of fighting range. The two large anemones in the foreground, however, appear to be headed for conflict. Right: A red and a blue* Phymaclis clematis *off the coast of Chile show battle scars where their light blue and pink acrorhagi tips have adhered and killed tissue.*

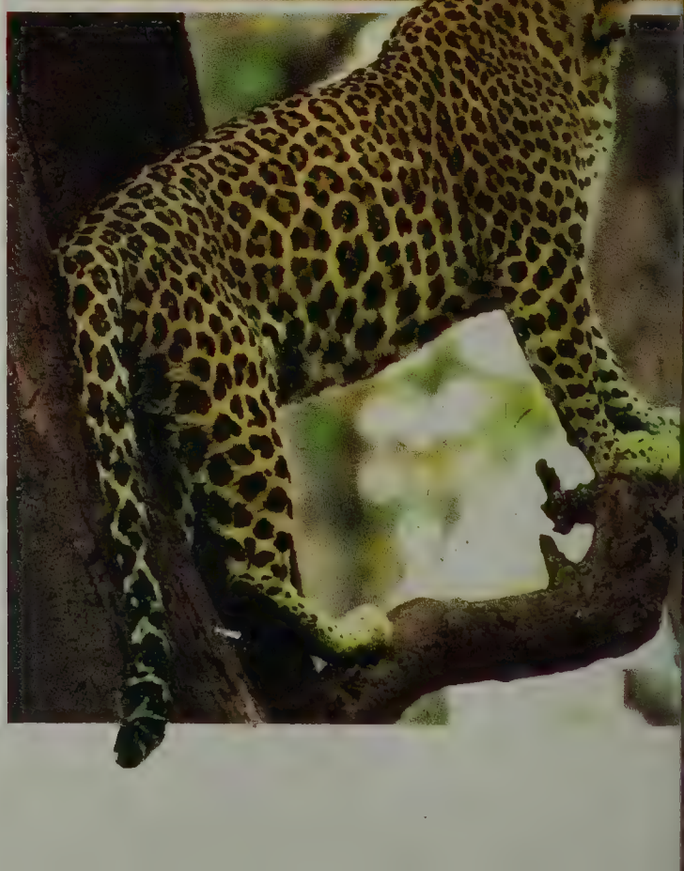
Ann Wertheim

found that some clones of *Metridium senile*, a common shallow water anemone throughout much of the Northern Hemisphere, tolerate each other but fight newly introduced clones and that, if forced into continuous contact, clones would habituate to each other and cease to inflate the fighting tentacles. Saul Kaplan, in a 1983 paper, presented the intriguing theory that *Metridium* fights only with clones of the same sex, never with those of the opposite sex. Laboratory experiments support the idea that sex recognition and segregation occur in this species. *Metridium* reproduces sexually by releasing eggs and sperm into seawater. Proximity to a clone of the opposite sex may increase the probability of eggs being fertilized.

Acrorhagi and sweeper tentacles are most often employed against other clones of the same anemone species. They are equally effective against anemones of other species and probably against corals as well. On coral reefs, anemones inhabit the interstices between living coral and often cover the surfaces of old coral rock. The large purple- or green-tipped Caribbean anemone *Condylactis gigantea* kills neighboring coral using its tentacle nematocysts, keeping the coral from growing over the anemone and interfering with its food capture. *Condylactis*, like the large anemones on temperate rocky shores (*Anthopleura xanthogrammica*), captures large mollusks and sea urchins that are rolled about by heavy wave action or that blunder into its tentacles.

If these agonistic behaviors were simply a matter of direct competition for space, the anemones might be expected to continue fighting until one clone won and could expand its area by asexual propagation. But there is always some space available on these rock surfaces. Although almost every square centimeter is covered by some plant or animal, many species can be overgrown or pushed aside by large anemones. Why, then, should a battle ensue? The message to newcomers from an established clonal group is, "This space is taken, go away." The response, with space available, may be, "I will do just that." But when space is scarce, and the newcomer settles down, a temporary battle will establish a border. Fighting tentacles or acrorhagi of adjacent anemones may then atrophy over time. If, however, individuals of one group wander too far over the border, the intruder's genotype will be recognized by anemones it has not contacted before and it will be attacked. On crowded reefs and rocky shores the anemone credo appears to be that good fences make good neighbors. □

Have the



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A Tale of Two Continents

India and Asia collided fifty million years ago, creating the Himalayas and the High Plateau of Tibet

Text by Paul Tapponnier • Photographs by Kevin Kling

The airport at Chengdu in the Chinese province of Sichuan is crowded despite the early hour. Almost all the planes are four-engine Ilyushins—well built but deafeningly noisy. The flight from Chengdu to Lhasa, the capital of Tibet, lasts more than four hours. This is the longest mountain flight in the world: 800 miles over peaks, most of which are higher than 16,000 feet. The plane must arrive before the June subtropical atmospheric turbulence begins. On this flight there are geologists and geophysicists from England, America, Italy, Canada, India, Turkey, Japan, and other countries. Most are going to Tibet for the first time. Many are professors or research scientists at famous institutions, yet they are both excited and impatient. Even a Chinese scientist is thrilled to point out on the map some places that he particularly wants to see. This 1986 international excursion, of which I am a member, follows a week of lively conferences and capped an exceptional adventure. Since 1980, every summer and fall, French and Chinese scientists have traveled thousands of miles together on the roof of the world to study the geological, geophysical, and geochemical structure of the earth's crust north of the Himalayas.

The curiosity and enthusiasm of the group are easy to understand. The Plateau of Tibet is by far the highest plateau on the planet: its average altitude exceeds 15,000 feet and equals that of the highest peaks of the Alps. These are the first geological expeditions in Tibet mounted by Western scientists since the Swedish expeditions led by Sven Hedin and Erik Norin and the voyages of individual pioneers at the beginning of the century. Tibet is still mostly an inviolate sanctuary that holds the key to the formation of a chain of mountains. Almost all scientists agree that these immense mountain ranges developed as a consequence of a collision between India and Asia. But when and how did that spectacular geological event take place? To find the answer one must travel across the mountains into the heart of Tibet, the inhospitable highland that is now an autonomous region of the People's Republic of China.

Pink sandstone, which gets its color from ferrous oxide, is one of the sedimentary rock layers in the Yangbajain Valley northwest of Lhasa. The magnetic orientation in this crinkled layer shows that this range has been pushed more than 1,250 miles north over the last fifty million years.

We land in a dry river bed at Gonggar airport, where a caravan of twenty jeeps awaits us. The air is dry and thin; the light almost unbearable. After just a few steps we feel slightly drunk at this altitude. There are no trees here except ancient willows growing along the edges of an irrigation canal. The scene is familiar: it resembles Skardu, in Kashmir, or Kabul, in Afghanistan. This is the heart of Asia. Eighteen miles west of the airport, a solitary bridge crosses the Yarlung Zangbo River at the village of Qüxü; Lhasa is about sixty miles away. The river level is still very low: the monsoon must cross the Himalayas in the south before it gains full force here in August. The wind, mainly from the west, blows the white sand around in the almost dry riverbed. Enormous dunes push against the sheer slopes. The sand masses were created by the erosion of a granite-diorite belt along the Zangbo's upper course.

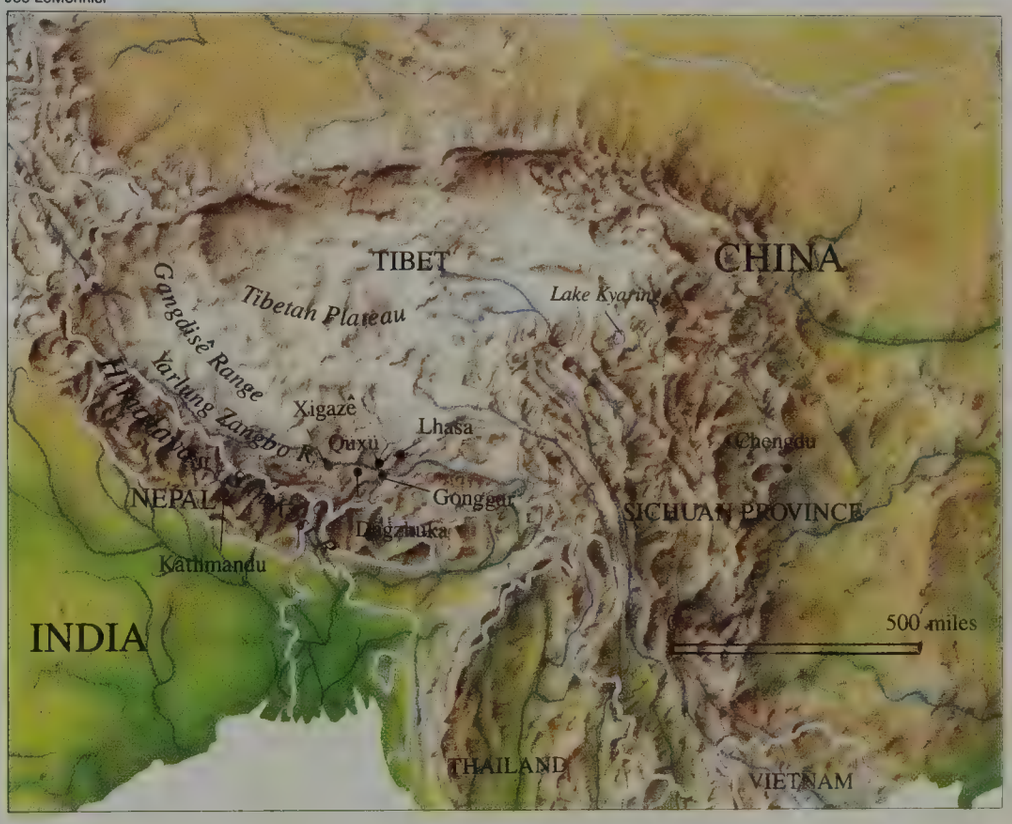
On the way to Lhasa, we enter the Gangdisê granite mountain range. The age and geological significance of this blue-gray granite are well known. The minerals that make up this magmatic rock—feldspar, quartz, zircon and sphene—contain small amounts of radioactive potassium, rubidium, and uranium isotopes. The slow disintegration of these isotopes, whose lifetimes are measured in billions of years, produces stable argon, strontium, and lead isotopes. This phenomenon is a reliable geological clock: the ratio of primary to secondary isotopes in the granitic minerals makes it possible to calculate the age of the granite.

Measurements made in Beijing and Paris place the age of this granitic rock at between 100 million and 50 million years—only yesterday in the long history of the earth. The granitic rock under the great lamaseries in the Lhasa Valley is a little younger at 40 million years. By now the development of such a mountain chain is no longer a mystery. According to the theory of plate tectonics, enormous quantities of molten rocks are generally formed where one plate, usually oceanic in nature, plunges under another and into the heat of the earth's upper mantle. This results in huge bubbles of magma rising to the crust of the upper, usually continental, plate. Part of the magma congeals in deeper regions forming layers of crystallized granite. The rest is thrown up to the surface by violent volcanic eruptions. This movement of plates enables geologists to reconstruct the geological landscape as it was long ago.

From the Mesozoic era (about 225 to 75

Tibet is one of the most seismically active regions of China. Left: A large fault scarp near Nagchu, northeast of Lhasa, was created by a major earthquake. The dark scarps running laterally across the steppe are left over from previous quakes.

Joe LeMonnier



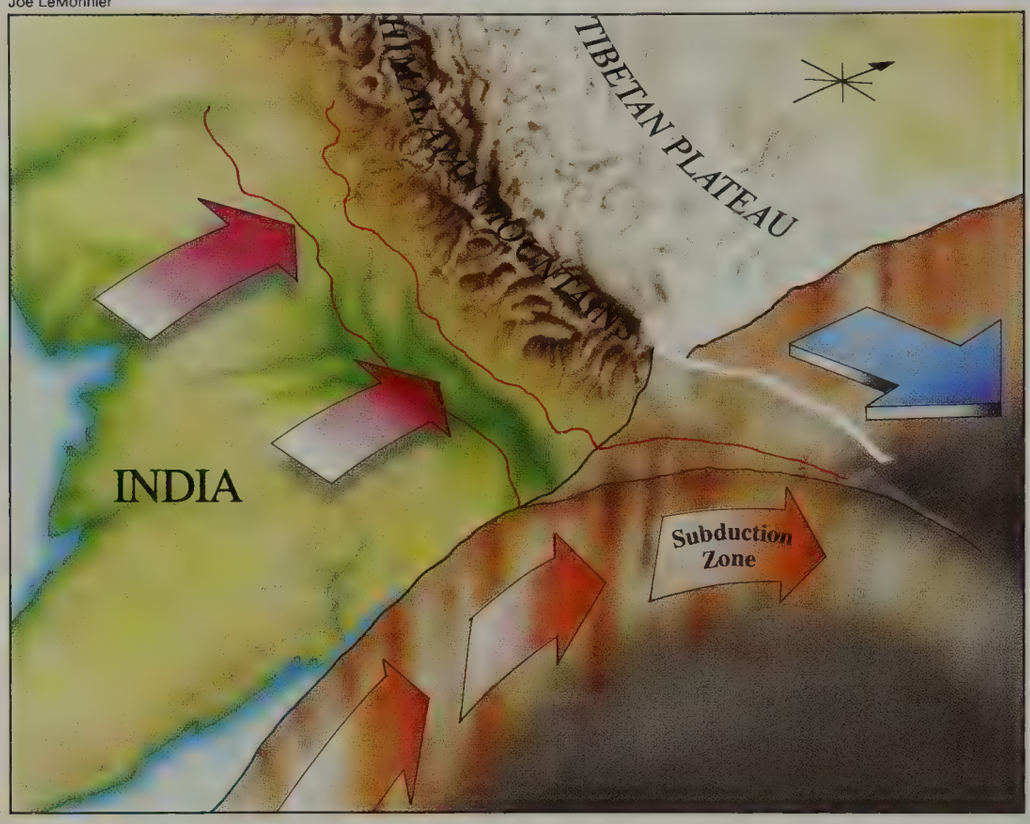
million years ago) to the middle of the Tertiary period (30 million years ago), the Lhasa region was at the southern edge of the Asian continent. To the south there was an immense sea—the Tethys. From time to time, severe earthquakes, similar to those in Chile or Alaska in our time, ravaged the shore because of the rapid underthrusting of the Tethys crust under Asia. As in the Cordilleras of the present-day Andes, powerful volcanoes poured lava and ashes along the Gangdisê granite mountain chain. Lava from the last cataclysmic eruptions, about 40 or 50 million years ago, still crowns the mountaintops around Lhasa.

Lhasa is situated in a large valley parallel to the valley of the Zangbo. When we arrive, we start feeling the effects of the rarefied air. We will stay at a hotel outside the city to acclimatize ourselves before pushing north toward the High Plateau. Thirty miles north of Lhasa, on the banks of the Yangbajain River, we find the first pink sandstones that show the effects of paleomagnetism, the earth's magnetic field as recorded in ancient rocks. The sedimentary sandstone rocks extend north as far as the center of the plateau in orderly layers and harmonious folds. They contain numerous animal and plant fossils that reveal the precise date, geographical environment, and climate of their formation. For example, there are trunks of big, low-altitude tropical trees. Some limestone layers indicate that the nearby Tethys Sea occasionally flooded the plain. The tiny fossilized animals in the limestone (foraminifers of the genus *Orbitolina*) were alive about 105 million years ago when this particular part of the Plateau of Tibet was in the intertropical zone (a belt of rising air that encircles the earth near the equator). The area was then a vast coastal plain covered with forests where winding rivers deposited sediments, rich in sand, which settled in horizontal sandstone layers. The paleomagnetic samples taken from various sites of the sandstone layer reveal how much the plateau has changed. They show that the ancient latitude of the region was more than 1,250 miles farther south than now. The only conclusion is that the Lhasa region, the Gangdisê mountain chain, and indeed most of the Tibetan Plateau, were pushed all those miles north by India's relentless penetration of Asia.

The paleomagnetic principle involved is simple: many rocks contain some proportion of magnetic minerals. The pink sandstone, for example, owes its color to ferrous oxides. When the rock is deposited or becomes chemically stabilized, the magnetic minerals behave like tiny compass needles and are oriented by the then-existing magnetic field. The lines of force of the earth's magnetic field are parallel to its surface at the equator, but everywhere else they dip toward the planet's interior at various angles. The angle of the dip is called "the inclination of the magnetic field." At the magnetic north pole the inclination is 90 degrees, and there the compass needle does not point to the north but straight down. The magnetic inclination varies from 0 to 90 degrees according to the latitude between the equator and the North Pole. The earth has always been

The suture zone along a tributary of the Zangbo River, right, marks the line along which India and Asia became welded. In 1986, an international scientific expedition visisted the zone. Before 1980, the area was closed to outsiders. Below: Over the millennia, India has moved northward from below the equator. Fifty million years ago it collided with Asia. The force of the collision welded the two continents and created the Himalayas and the Tibetan Plateau. India is still pressing against Tibet. In the process, the northernmost part of India is being forced under Tibet, and China is slowly being pushed eastward toward the Pacific.

Joe LeMonnier



an immense bipolar magnet with the poles close to its axis of rotation; consequently, the magnetic orientation of a rock determines the latitude at which it was formed. This is why the small samples of pink sandstone from Tibet tell scientists that about 100 million years ago the Asian shores were near the equator.

Seismological profiles worked out in Tibet by the French-Chinese teams made it possible for the first time to determine the thickness of the continental crust in the northern Himalayas. These profiles were based on artificial seismic waves generated by explosives. They indicate that the Mohorovicic discontinuity, or Moho, the boundary that separates the rocks of the earth's crust from the denser rocks of the mantle, plunges more than forty-six miles under the Tibetan Plateau. This is the thickest crust on the planet and explains the plateau's high altitude: when a continental plate is in isostatic equilibrium, the gravitational effect of the mass of material in the crust is equal to that in the underlying mantle. Thus, the thicker the crust, the higher the surface altitude.

Belying the ancient upheavals sealed in its depths, the plateau's monotonous surface seems to reflect a present-day tectonic tranquillity. This is, however, only an appearance. According to the seismic history of China, Tibet has been the most seismically active region in the country since the beginning of the century, with many earthquakes registering about eight on the Richter scale. A thorough examination of high-resolution photographs taken by a Landsat satellite at an altitude of 560 miles has enabled the French and Chinese tectonics experts to discover and study in detail the fresh surface scars caused by thousands of years of earthquakes.

An earthquake is a violent breaking-up of a cluster of rocks by pressures built up in the earth's crust over centuries and millennia. Such a breakup in the continental crust usually occurs at a depth of about six miles and spreads over an almost even plane called a fault, causing one of the two rocky masses separated by the fault suddenly to slip in relation to the other. The magnitude of the earthquake depends on the surface area of the fault and the extent of the movement. For a very big earthquake, the movement may exceed thirty-three feet on a fault that is often several hundred miles long. The direction of the slip is one of the most valuable pieces of information for studying present-day deformations of the earth's crust, since these deformations result from a great number of earthquakes over a long period of time.

Recent tremors in Tibet reveal two types of sudden movement connected with India's penetration of the Asian continent. At Lake Peng the Tibetan prairie is scarred along a ninety-mile-long line from east to west, the result of the earthquake of November 18, 1951, which registered eight on the Richter scale. Thirty years later the prairie is still mangled, full of gaping crevices and waist-high creases, as if the quake had occurred only yesterday. In less than a few seconds, the rocky mass north of the fault line moved forty feet to the southeast. There is a similar but shorter dislocation to the west at another

narrow lake, called Kyaring. It is probably traceable to a 1934 earthquake (seven on the Richter scale) and indicates that the zone north of the fault line moved eastward. This means that the entire Tibetan Plateau moves eastward a few feet a century: that is, in its northward progress, the Indian continent is pushing most of China toward the Pacific Ocean.

In the mountains closer to Lhasa, north–south faults show another type of movement. These fault lines are especially spectacular on the road from Lhasa to Xigazê, where a linear basin has been dropped down thousands of feet with respect to the surrounding peaks, some of which reach 20,000 feet. The faults at this narrow corridor's edges were once so active that they produced 125-foot-Quaternary glacier beds, formed about a million years ago. The magnitude of these movements even impresses the geologists in our party who are used to the great dimensions of the American West. Hot springs and geysers gush at the bottom of the rift. The power they generate is harnessed by a geothermal power station that will soon feed electricity to Lhasa.

Satellite pictures show a lot of identical north–south rifts all over the High Plateau, suggesting that it has stretched in an east–west direction and become narrower. This phenomenon does not seem to have started before the beginning of the Quaternary period, about two million years ago. What seems to have occurred is that Tibet acquired its high altitude after the onset of the collision with India. When the crust was unable to thicken any further, it stretched in a direction perpendicular to India's movement.

Throughout south Tibet the Zangbo River Valley follows the line, or suture zone, along which the Indian and Asian continents collided and became welded together about fifty million years ago. This suture zone is one of the most famous zones of its kind, but until 1980 it was closed to scientists. They had to be content with studying the zone's extension in Ladakh, in northern India, and in Pakistan or Afghanistan. That zone was perhaps the most interesting part of our journey.

We traveled southwest from Lhasa to Xigazê and arrived at the suture zone at Dagzhuka, where we crossed the Zangbo River. In the middle of the river a reef is left uncovered by the low water, revealing unusual rocks of deep green, almost black lava basalts. South of Dagzhuka we found entire hills made of these rocks. Originally formed underwater, they have a peculiar structure that makes them look like stacks

of little pillows, which is why they are called pillow lavas. In the mountains along the Zangbo between Dagzhuka and Xigazê, pillow lavas cover other, better-crystallized rocks: the deeper equivalents of basalts called gabbros, and the still deeper peridotites (named for the olive green semiprecious stone olivine, or green garnet, that is its main ingredient). The peridotites are no longer in the crust but in the upper mantle. All these green rocks are covered with a fine, often red, siliceous sediment called radiolarite, which is characteristic of deep volcanic seabeds.

The grouping of crystallized rocks is recognized today as a sure sign of vanished oceans. The typical rock strips that mark the Zangbo suture are flakes of the crust and mantle of the Tethys Sea, which separated Asia from India before the collision. The rocks of Xigazê, which only 100 million years ago were on the bottom of the ocean under more than 16,000 feet of water, are now 13,000 feet above sea level. The region contains the last vestiges of thousands of miles of seabed left there, as though by mistake, by the Gangdisê volcanoes that swallowed it up.

In our study of this former seabed we tried to reconstruct the successive positions of India relative to Asia. We discovered that about 80 million years ago India was approximately 4,000 miles south of Asia. It then moved "fast," more than thirty feet a century, until about 50 million years ago, when its speed dropped to roughly fifteen feet a century. There is absolutely no doubt that this tectonic slowdown occurred when India was welded to Asia. The Tethys Sea was rapidly swallowed up and died before that. The colossal collision of the two continents created the Himalayas and the Tibetan Plateau. That collision is the same force that still shakes China from time to time. Before all this happened, the Tethys must have been between two and three thousand miles wide, about the size of the present-day North Atlantic.

Farther to the south of the Zangbo, in the zone between China and India, the colorful environmental confusion is replaced by a gray monotony. We arrived at India's edge, the southern shore of the vanished Tethys. This area, formed about 200 million years ago, was the site of a calm and regular sedimentation until the collision with Asia. It used to be a placid shore hemmed by a large continental shelf where, during the Triassic and Jurassic periods (240 to 140 million years ago), great reptiles frolicked in the shallow water. There were no erupting volcanoes or

The dark rocks behind the sand dunes, left, once 3,000 miles under the sea, are now at an equivalent altitude above sea level. Folded limestone crests in Mesozoic sediments, below, rise in occasional toothlike formations. The Shekar Dzong monastery, bottom, is camouflaged in an even steeper rock formation. Some of the crests above the monastery are man-made, mimicking the real thing.

devastating earthquakes. Peaceful rivers deposited their mud in the vast deltas. Sometimes the enormous masses of sediment and wet sand collapsed under their own weight, unleashing avalanches into the deep water north of the Indian continental shelf. A similar avalanche running down the continental slope over the Grand Banks of the North Atlantic tore apart transatlantic telephone cables in 1929. The same kinds of avalanches created the gray marine sediment that hemmed the northern edges of the Indian continental island and that we find at present south of the suture zone of Zangbo.

In this zone the folds are not straight and symmetrical like the pink sandstone folds north of Lhasa; rather, they lean southward, like waves breaking on a shore, and the effect of the collision of the two continents can be seen more sharply. Entire rocks formed by thick sedimentary accumulations overlap one another in a southerly direction, with the northern rock always overlapping the southern rock in the succession of folds. The tectonic upheaval that formed the mountains after the collision becomes a reality here and the tranquillity of the Tibetan Plateau is far away. Our first visual impression of the suture zone is that the edge of Tibet is breaking into a succession of waves against the Indian plain.

Now, about 50 million years after the disappearance of the Tethys's crust under the Gangdisê mountain chain, the Indian continental plate continues to plunge under Asia, but at a slower pace. The zone of the phenomenon has been shifting too, from the Zangbo suture to the south, and it is now situated on the Nepalese slope of

Fields of colza, or rape, grow just outside the village of Xigazê in the Zangbo Valley.

the Himalayas. The Indian continental crust, relatively thick and light, cannot sink as easily as the thinner and heavier ocean crust, such as that exposed in the suture zones farther north.

From Tingri, in China, the road to Kathmandu, in Nepal, swerves away from the Himalayas and then, after a 16,000-foot-long pass, turns to the south to start a dizzying descent in the shadow of the 26,287-foot mountain of Xixabangma. This is where the Tibetan Plateau ends and the Sun Kosi River cascades down to the Gangetic Plain. Within twelve miles the pure desert cold of the highlands gives way to the hot haze of the tropical forest. Left behind are the surface sediments and the famous white granites that cooled a mere fifteen million years ago and today constitute parts of some of the highest peaks in the Himalayas.

As we move south we enter the center of the Himalayan continental overlap. The underlying rock here slid northward an estimated 125 miles under the overlying rock. In addition to the several-mile-thick sedimentary shavings that overlap here, there are also overlapping slices of the continental crust. Sliding under Tibet, the Indian plate has been "shedding" the upper part of its crust, where the rocks were first planed by Asia's edge and then piled up. The slices of the Indian upper crust make up the high mountain chain of the Himalayas. The great overlapping fault lines in the crust have migrated south. The action has already shifted about sixty miles south to a young and seismically active overlap at the edge of the Gangetic Plain. Underneath, India progresses slowly and relentlessly. If no force stops it, Kathmandu will be the peak of a new Himalayan chain in ten million years.

As we leave for home, we realize that in spite of the progress we have made, Tibet remains a great scientific puzzle. Even if we understood more about the formation of the Himalayas and the death of the Tethys Sea, the High Plain north of Zangbo would remain full of mysteries. We still have no idea how or when the plain was born. And we appreciate, perhaps more than before, how difficult it is to probe our planet's past. □

Snake, Rattle, and Roll

In the face of short summer seasons, the search for food and sex drives prairie rattlesnakes across long stretches of high western desert

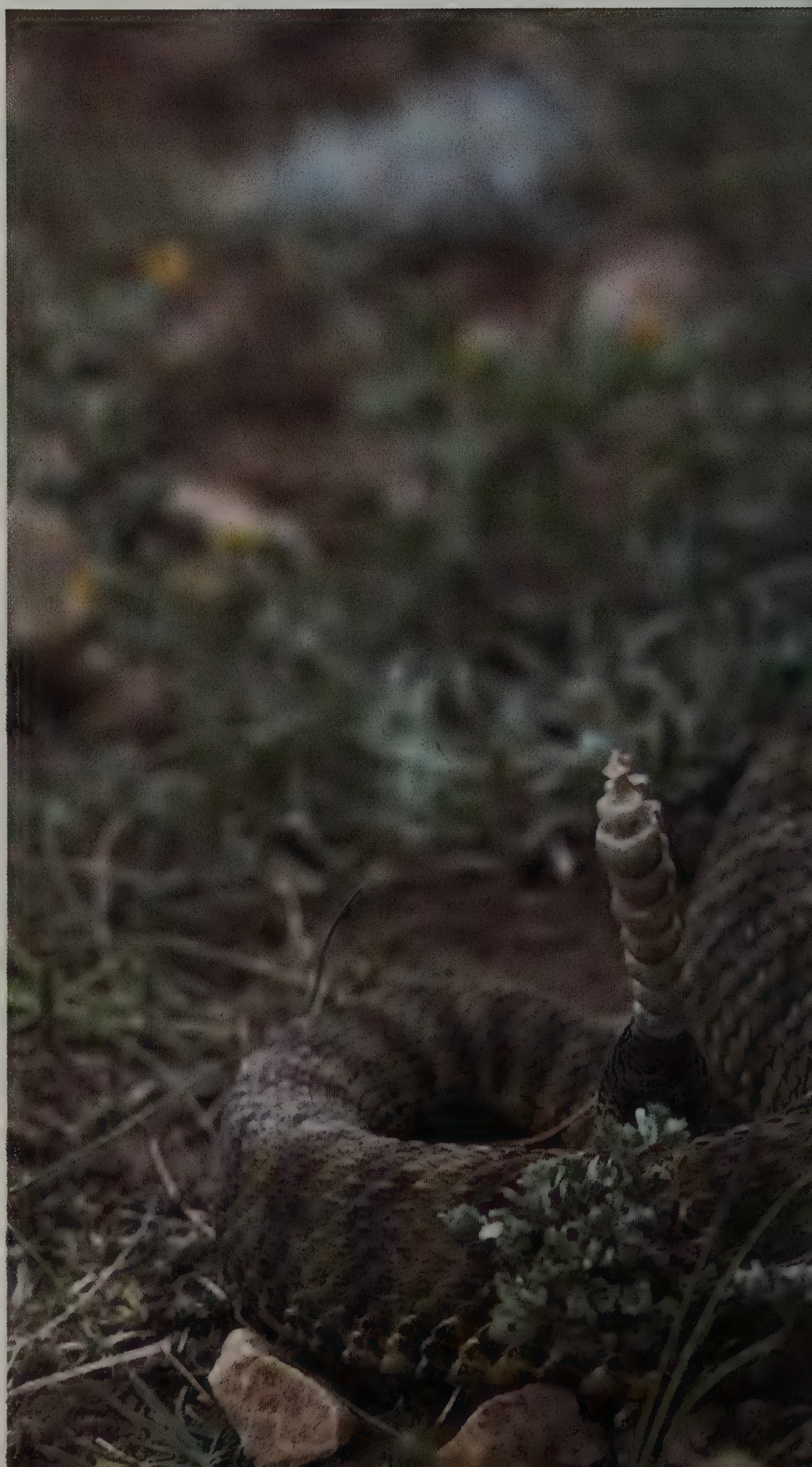
by David Duvall

The deserts and plains of south-central Wyoming are high-and-dry sagebrush flats interspersed with talus-covered hillsides and ephemeral streams. Rabbit brush, greasewood, prickly pear cactus, and short grasses grow in patches on the bleak sand and stone. Winters are long, and during the short summers, temperatures can reach ninety-five degrees during the day and fall to forty-five degrees at night. Rainfall is barely twelve inches a year. Even experienced naturalists are sometimes surprised by the variety of wildlife that this spartan habitat supports. One of the most specialized is the prairie rattlesnake (*Crotalus viridis viridis*), one of eight subspecies of western rattlesnake and the most widely distributed species of pit viper in North America.

Rattlesnakes elicit both great fear and great curiosity, yet little is known, outside of anecdote and outright myth, about their habits in nature. Secretive and well camouflaged, they are difficult to observe, and so the nature of their annual migrations has remained a mystery, especially on these high prairies.

Based on studies done in more lush and southerly environs, biologists thought that the prairie rattlesnakes of the high plains were drifters, leaving their dens after a winter's hibernation and wandering—ambushing whatever prey happened by and never traveling more than a few miles from their dens. Our studies provide evidence to the contrary. In the face of short summer seasons, the search for food and sex can lead prairie rattlesnakes on migrations of seven miles and more from their canyon hibernacula.

In the Haystack Range, south of the Seminoe Mountains, roughly twenty-five miles north of Sinclair, Wyoming, and a mile east of the Continental Divide, Wyoming University students Mike King, Brent Graves, Al Redder, Matt Goode, and I studied a group of prairie rattlesnakes that hibernate from October to May in dens in Coal Creek Canyon. After seven months in the total darkness of their communal dens, the snakes emerge and, for the next couple of weeks, remain within a hundred feet of the den entrances. During this time the animals may

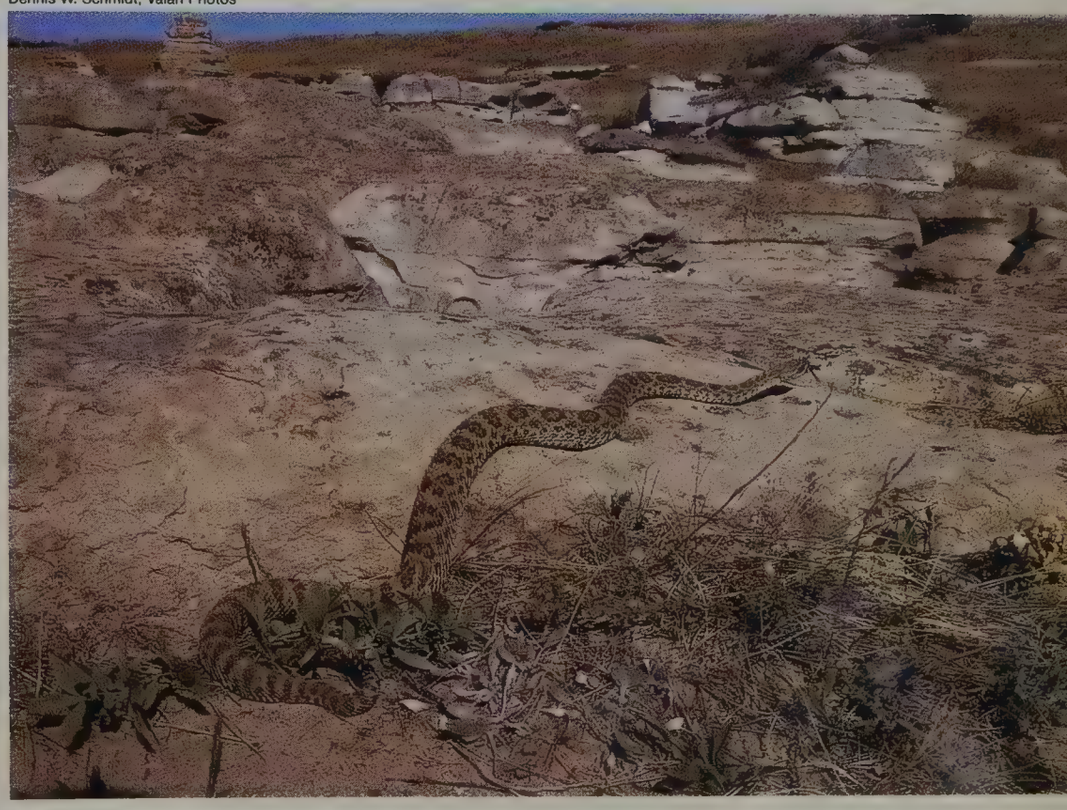


Head up, neck cocked, and rattling, this prairie rattlesnake strikes a classic coiled pose. Although often described as an aggressive posture, this behavior is, in fact, defensive. It comes only after the snake has tried to elude its attacker by lying still, camouflaged in the grass, or has had its escape routes blocked.
Jeff Foott

Jeff Foott; Bruce Coleman, Inc.

Left: Upon emerging from the den each spring, prairie rattlesnakes bask nearby. Below: Once reoriented to their surroundings and sufficiently warmed to journey, the snakes begin their migrations, usually traveling in the mornings and perhaps orienting to the sun.

Dennis W. Schmidt; Valan Photos



reset their biological clocks and orient to the sun, which will guide their summer movements.

We studied more than four hundred snakes from this canyon; eighteen adult snakes were studied with radiotelemetry in four field seasons of work. We captured them as they emerged from the den and implanted radio telemeters in them. After a few days of recuperation from surgery, they were released again at the den entrance, followed daily through the summer, and all their movements recorded. We set traps for small mammals, such as mice and ground squirrels, along the snakes' routes to see if the reptiles were passing through areas in which prey was abundant.

Spring migrations are characterized by long-distance movements. Snakes travel in the morning and late afternoon, remaining in small holes and crevices during the hotter times of the day and through the night. Perhaps to reduce the risk of predation when moving across open terrain, the snakes often begin their migrations with the onset of severe thunder and rain storms, conditions that limit the foraging of eagles, hawks, badgers, coyotes, bobcats, skunks, foxes, and humans—all known predators of these serpents. Snakes from this population often covered more than half a mile a day. Over the vernal migration period of two to three weeks, the snakes traveled an average of more than three miles (one even traveled eight miles). These journeys, moreover, were virtually straight-line routes, though the reptiles frequently traveled up steep hillsides and through large canyons. Our trapping efforts along a snake's route produced no results until migration stopped. Only then did we begin to catch small mammals, primarily deer mice.

We believe that during vernal migrations prairie rattlesnakes assess the density of small mammal populations by monitoring the concentration of mouse odor. Rattlesnakes flick their tongues continuously while moving, occasionally yawning, or mouth-gaping; in this way odorous molecules reach the vomeronasal organ (chemically sensitive nerve endings) in the roof of the mouth. Where mouse odors are concentrated, mouse populations will likely be dense. While a variety of prey, including ground squirrels, young rabbits, voles, and birds, may be available, our

Along their migration routes, snakes often explore rock crevices for prey and seek shelter for the evening. At the end of summer, however, they return to the dens that they left in the spring. These dens, high up on canyon walls, have been used by snakes for thousands of years.

William Ervin

data indicate that it is the presence of the deer mouse (*Peromyscus maniculatus*) that guides the rattlesnake migrations. David Chiszar, of the University of Colorado, found that snakes often spend several hours a day in ambush postures where rodent odors are concentrated.

When some threshold of mouse odor concentration is encountered, rattlesnakes cease their migrations, presumably satisfied that the area will provide sufficient prey. Should prey become scarce, rattlesnakes may make short movements searching for new areas. But, generally, individuals settle in their selected spot for much of the summer.

The snakes take up residence in the burrows of small mammals and wait for the prey to return. After the envenoming strike, tongue flicks and mouth gapes are frequent, as the snake sweeps its head back and forth, tracking the wounded rodent by its odor to the site of death. Such trailing is chemosensory and extremely precise; David Chiszar has observed that the snake's head never deviates more than a few inches from the mouse's path. When the dead prey is located, the snake again uses its chemical senses to find which is the head and which is the tail end of the rodent and then begins swallowing it head-first. Such feedings may occur several times throughout the summer, although no one knows how frequently rattlesnakes eat or what their energy requirements are in the wild.

These areas are also the staging sites from which male prairie rattlesnakes make forays for mates; a demanding task, since during any summer only half the females in a population will be receptive to mating. The other half are pregnant and have not made the long migration, remaining instead in birthing rookeries close to the den but farther down the canyon wall. Later in the summer their live young will be born in these protected rock areas. This two-year breeding cycle further complicates the male's life because receptive females can store sperm from one year to the next and so may be able to produce young even in a year when they have failed to mate.

Females that have migrated to the feeding grounds may be followed by several males. The first encounters between a breeding pair may be tentative and several days may elapse before the female allows the ritualized courtship to begin. When she does, the male moves up and down the female's body, rapidly flicking his tongue and pressing his chin along her dorsal surface. The tongue flicks carry signals to the chemical sense organs, assuring him that he is attempting to mate with an appropriate object and assuring her that it is truly a male rattlesnake crawling over her. Male snakes (and lizards) possess two copulatory organs, which are stored inverted within the tail. During copulation, one of these spine-covered hemipenes is everted and inserted into the female's cloaca. In

Oblivious to outside stimuli, snakes entwine during copulation, the male moving up and down the female's body, rapidly flicking his tongue and pressing his chin along her dorsal surface. Only half the population of female prairie rattlesnakes is fertile in any one year. The rest are preparing for the fall birth of live young at rookeries along the canyon walls.
Jeff Foott

each of four matings that we observed in the field (all in mid to late summer), intromission lasted approximately ninety minutes (though longer copulations have been reported in other rattlesnake studies). Afterward the snakes parted company with no further interest in each other.

Emerging from the den in spring with the other snakes, pregnant female rattlesnakes do not move far, preferring to forage for what is available in the area and gathering in the communal rookeries for warmth and protection. The rocks under which the snakes lie absorb the sun's heat and, along with the snakes' body mass, retain some heat until warming begins again in the morning. The collective warmth of the birthing rookery hastens the development of the eggs within the female snakes. Gathering for the benefit of the young may indicate a primitive social behavior on the part of these usually solitary creatures. Pregnant females using the rookeries give birth sooner than snakes that remain outside of them. Their young may then have a better chance to locate suitable holes in which to hibernate before the onset of winter.

Baby rattlesnakes are born in the rookeries in late August and early September and have barely three weeks between birth and the time they must be safely within a hibernaculum for the winter. For one to two weeks after birth, the young do not set off in search of an overwintering site. This is also when they first shed the outer skin layer. Brent Graves found this layer to be significantly different from subsequent skin layers in that it contains fewer of the fats and waxes, called lipids, that provide waterproofing to the skin. The young snakes wait at the rookeries

until a more resistant outer layer of skin is developed and then disperse to the dens.

They may follow the same chemical cues to the dens that guide adult snakes home at the end of their fall return migration. If lipids in the skin of rattlesnakes rub off on rocks, bushes, and gravel as the snakes move, they, along with shed snakeskins, may be the sources of odors assisting den location. We have found that exposure of young snakes to skin lipids from adults induced increased tongue flicking. Further, when given a choice, young snakes are attracted to rock piles marked with skin lipids of adult snakes, rather than to unmarked rock piles.

By the end of August, in response to shorter days and falling temperatures, snakes begin their return migration to the den. Their route follows the same angle (though not the identical path) that was traveled in the spring. They use the sun for orientation, as they do during spring migration and may also employ geographical landmarks. As they approach the den area, they probably use the vomeronasal organ to pinpoint the one crack in the rock-covered hillside that is the den. If it chooses a crack that does not provide sufficient protection from the subfreezing temperatures of the long Wyoming winter, a rattlesnake will freeze to death. Communal hibernation and birthing aggregations appear to be unique to snakes in extreme climates, behaviors that evolved in response to harsh conditions.

During September and October more and more rattlesnakes, along with wandering garter snakes (with which they will share the warmth of the communal den), arrive at the den. On warm days, many of them can be found sunning near the den's entrance. Since additional meals are unlikely to be secured after they reach their communal hibernaculum, sun basking around the entrance in fall may aid digestion of the last meal, and female snakes may stay warm to enhance ovarian maturation. Males remain out of the den in order to copulate with any still receptive females that arrive. Soon, however, the snakes will retreat into the canyon dens that have served as winter refuges for thousands of years. □

Below: A young snake about three years old basks next to an adult. Females return to the dens from the rookeries two to three days after giving birth. The young snakes find their way to the dens within ten days. Upon returning to their dens in the fall, groups of thirty to forty rattlesnakes can be seen basking for days in preparation for their winter hibernation.

Jeff Foott

Tionesta Forest, Pennsylvania

by Robert H. Mohlenbrock

Shortly after six on the sultry evening of May 31, 1985, tornadic winds roared eastward across the Allegheny River and slammed into Pennsylvania's Allegheny National Forest, toppling hundreds of trees and shattering thousands of others. The violent twisters slashed six corridors through the forest, one nearly a mile wide, before coming together for a final fling at the western edge of the community of Kane. In a matter of minutes, a violent arm of nature destroyed what another, more tranquil side had taken hundreds of years to build. One path of devastation pierced the heart of Tionesta Forest, one of only two stands of virgin hemlock remaining in Allegheny National Forest.

Before the arrival of European colonists, some six million acres of the Allegheny Plateau in Pennsylvania and New York were covered by a forest dominated by eastern hemlock, American beech, and sugar maple. But little uncut forest remained by 1936, when the Federal Government purchased 4,000 acres to preserve a remnant of this biological community. In 1973, the Tionesta Scenic Area and Tionesta Research Natural Area, into which this tract is officially divided, were placed on the National Register of Natural Landmarks.

Since 1936, biologists have observed the ecology of Tionesta continuously, re-

Todd Powell

Eastern hemlock seedlings take root in a virgin forest devastated by a tornado

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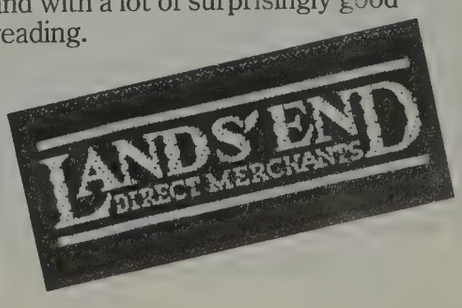

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cording the area's development. Eastern hemlocks grow up to 125 feet high, with diameters of four feet. Nearly as big are the American beeches and sugar maples. Black and yellow birches, yellow poplar, cucumber magnolia, basswood, red maple, and white ash are some of the other trees scattered throughout the forest. Beneath the canopy, shrubs, including the maple-leaved viburnum and another type of viburnum called hobblebush, grow eye-level high. The forest floor is alive with nearly seventy-five wildflower species and a variety of ferns (areas of up to one acre are a sea of light green because of the abundance of the spinulose wood fern).

Some of the larger animals in Tionesta have a conspicuous role in shaping the composition of the forest. Porcupines feed on the bark and inner tissues of many of the trees, ultimately girdling and killing some of them. The porcupines seem to prefer beech and hemlock, but sugar maple and yellow birch also rank high on their menu. White-tailed deer forage on hemlock and maple seedlings, and they apparently relish hobblebush, sometimes nibbling away until it is eliminated from an area. Since the deer spare the beech seedlings, these are abundant in some parts of the forest.

The 1985 tornado, however, abruptly halted normal life in a segment of the forest and sent things back to square one. As a result, biologists now have an ideal opportunity to observe how a virgin hemlock forest recovers.

After 1863, when Anton Kerner published his landmark study of Europe's Danube Basin, biologists came to realize that in most plant communities, plant groups are constantly replacing one another, a phenomenon now referred to as plant succession. Succession occurs in many habitat types. A new lake bottom, for example, is at first barren of plant life, but soon microscopic plants and animals die and fall to the bottom, forming a layer of organic muck. As the lake bottom's oozy layers thicken, aquatic plants, such as pondweeds, take root. These rooted plants also add organic matter to the lake bottom, creating an environment conducive to the growth of cattails, bulrushes, and other emergent plants. As the years pass, a shrub stage may develop, followed by such trees as willows. Lakes all over the globe follow the same sequence.

Similarly, during the first year following abandonment of a midwestern farm field, small plants that complete their life cycle in one season usually prevail. In subsequent years, these annuals are joined by certain perennial herbs that eventually crowd out and eliminate the annuals. Grasses, notably broomsedge, arrive a few years later, and compete with the other perennial herbs. A shrub stage then develops, with sumacs, young sassafras and persimmon trees, and perhaps rough-leaved dogwood. The shade these shrubs provide permits seedlings of maple, oak, and hickory to survive. As they grow, these tree seedlings overtop the shrubs and form the canopy of a forest.

In general, succession involves the replacement of limited plant communities, which produce relatively little living matter, by more complex and increasingly stable plant communities, which encompass far more "biomass." Once a community develops that will persist for a long time under natural conditions, succession is said to have reached the climax stage.

In the Tionesta Forest, the successional climax is a community dominated by eastern hemlock, American beech, and to a lesser extent, sugar maple. Seedlings of these trees have a high tolerance for shade, surviving for years under the dense canopy created by their parents. Seedlings of most other trees perish under these conditions. When one of the giant hemlocks or beeches or sugar maples dies of old age and falls, seedlings are ready to grow into the opening created in the canopy.

Todd Powell

One year after the 1985 tornado, its path remains etched in Tionesta Forest.

TRUE or FALSE

Mark each of the following statements T for True, or F for False, in the box at its right. For correct answers, see panel below.

1 — If a husband does not have a Will and therefore dies "intestate," state law will give his wife all of the Estate. ☐

2 — If you die "intestate" while your children are minors, state law will divide a third of your Estate among them. ☐

3 — When you leave no Will, the state automatically appoints a social worker and a bank as guardians of your minor children. ☐

4 — Whoever is appointed guardian for your minor children has complete say-so in taking care of them and their affairs. ☐

5 — Lacking a Will, your property will be disposed of more or less as your Will would have directed. ☐

6 — Children not mentioned in your Will are excluded from an inheritance. ☐

7 — A husband has the same rights to his wife's Estate as she has to his. ☐

8 — A handwritten Will, unwitnessed, cannot be valid. ☐

9 — Wills never require more than two witnesses. ☐

10 — It is expensive to have a lawyer draw up your Will. ☐

Can you answer these questions about writing your Will?*

ANSWERS

1 — False. Usually not. In some states, the wife gets one-third if the husband dies without a Will.

2 — False. Many states give two-thirds of your Estate to your children equally divided among them.

3 — False. It is more likely to appoint your spouse as guardian, or some other person. But they will have to furnish a bond and pay the fee for it.

4 — False. Even if your spouse is guardian, he/she usually must have specific permission from the court to spend your children's share of your Estate on their support or education. He/she may be required to render detailed accounts of these expenditures.

5 — False. Your property would be disposed of according to the law of your state and not necessarily as you would have directed.

6 — False. A child born after the date of your Will might be entitled to receive whatever would have been provided by the state if you had died "intestate."

7 — False. This is not always the case.

8 — False. In some states, when the handwriting is generally known, handwritten Wills can be held valid, but questions about the circumstances under which they were written make them a very risky proposition.

9 — False. Some states may require three. Any Will disposing of property located in a three-witness state should have three, even if you write it while resident in a state requiring only two.

10 — False. Actually, it is usually a very modest amount. Whatever his charge, the expert knowledge involved makes it a bargain.

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Because Tionesta was virgin forest and was designated a Natural Landmark, Forest Service personnel decided to let succession take its natural course after the tornado. Nothing was done to tidy up the area or promote the growth of particular species. Giant trees three feet in diameter lie where they fell. Elsewhere, upright splinters are all that remain of trees shattered where they stood.

Four months after the tornado, thousands of eastern hemlock seedlings had germinated alongside the forest debris. In the meantime, species that previously had been suppressed by the deep shade began growing in the open. Blackberry bushes and young trees of wild black cherry came up with a vengeance in the spring of 1986. For a few years, until the young hemlocks grow tall enough to shade them out, these species will form nearly impenetrable thickets. Once the blackberries and wild black cherries are reduced, however, spinulose wood ferns, thriving in the shade provided by the hemlocks, will probabl once again carpet the forest floor.

On a visit to Tionesta before the to nado, I had driven to the forest's parkin area and hiked a narrow trail that mean dered under the hemlocks and beeche When I returned in May 1986, I saw tha the tornado, which skirted the parkin area, seemed to have used the hiking pat as one of its boundaries. On one side virgi forest still stands as it must have appeare hundreds of years ago, while on the othe side is total destruction. At one plac along the trail, I reached out with my righ hand to touch the living trunk of a 100 foot tall hemlock; my left hand extende to a splintered dead beech tree whose to lay across the devastated area.

"This Land" highlights the biologica phenomena of the 153 U.S. national for ests. Robert H. Mohlenbrock is distin guished professor of botany at Southern Illinois University at Carbondale.

Alan Perkins: The Image Farm

In order to study the natural succession of plants, the Forest Service decided not to disturb Tionesta's toppled hemlocks.

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Mars and Jupiter Are Most Valuable Players

by Thomas D. Nicholson

Don't look for much excitement in the November sky this year, unless the winter stars turn you on, and even they don't take up good postions for viewing enjoyment until about 10:00 P.M. or later. Plenty is happening in the sky, but not much of it will be visible to us. Take Saturn and Antares, for example. All this year they have been sharing Scorpius like twin stars, distinguishable best by Antares's reddish yellow color. They may have looked as constant as two stars, but Saturn, we know, edges slowly leftward because of its easterly motion in the solar system, even though it progresses so slowly that watching it is like watching trees grow. Saturn and Antares are still evening stars, but they set before the sky darkens sufficiently to enable them to be seen.

Two planets we *can* see, Mars and Jupiter, are early evening objects, well up in the south at sundown and setting low in the west about midnight. The stars around them in Capricornus and Aquarius offer no competition, so they stand out when skies are clear. Jupiter is by far the brighter of the two; Mars, although only five months from its brilliant opposition, has faded to a fifth or less of what it was in July. When the moon comes along in the second week of the month, just past first quarter, it makes the scene especially worth watching.

Mars and Jupiter also show off their motion in the solar system by drifting through the stars, and the closer they get to the sun, the faster their approach. Mars cuts its distance to Jupiter by half this month, now that it is a quarter of the way around the sky from the sun.

Events described in the calendar below are given in local time unless otherwise indicated.

November 1: The moon crosses the border between Virgo and Libra but is up only in daylight or bright twilight, and the old crescent is too thin and dim to see.

November 2: New moon is at 1:02 A.M., EST. Mercury begins its retrograde (westerly motion), backing toward the sun more rapidly now.

November 3: Saturn is in conjunction with Antares. When we see them again in the morning sky (in late December), Saturn will be to the left (east) of the star. The moon is at perigee (nearest the earth) at about 9:00 P.M., EST, and earlier in the day it passes so close to Mercury that it covers the planet (an occultation) over southern South America and Antarctica.

November 5–6: Venus moves between the earth and the sun today on the 5th (inferior conjunction), entering the morning sky. It will burst out to the right of the sun as a brilliant morning star this coming winter. The new crescent moon will be visible in the western sky during early twilight on both nights. It is in Sagittarius, but the stars around it are too low to see by the end of the typically long near-winter twilight.

November 8: Jupiter ends its retrograde drift and starts moving eastward again along the ecliptic. The moon is at first-quarter phase at 4:11 P.M., EST. By nightfall it will pass from right to left below Mars in the southern sky, moving between Mars and the brighter Jupiter.

November 9–10: The moon is still between Mars and Jupiter on the night of the 9th, passes south of the brighter planet at about 2:00 P.M., EST, on the 10th, and will be to Jupiter's left on the night of the 10th. The moon and the two planets make a bright and handsome threesome on both nights.

November 12–13: Mercury's inferior conjunction (between the earth and the sun) occurs at about 11:19 P.M., EST. The planet's orbit is positioned to bring it directly across the disk of the sun. For observers who are favorably situated, Mercury will appear as a tiny dark dot moving from left to right across the sun's face, taking about four hours to complete the transit. Unfortunately, the planet's entire transit will take place while Mercury is below the horizon from most of North and South America. A small portion of the transit will be visible before sunset in Hawaii and western Alaska, and all or part of the event will be observable from most of Europe, Asia, Africa, Australia, and many places in the Pacific.

November 16: The moon is full at 7:12 A.M., EST, and it moves into Taurus this evening. The bright reddish star Aldebaran is nearby.

November 19–20: Gemini is home to the moon these evenings as it rises after sunset. The stars to the left and below the moon (closer to it on the 20th) are Pollux and Castor. Apogee moon (farthest from the earth) is on the 19th.

November 22–23: Mercury, after passing between the earth and the sun, resumes its direct easterly motion on the 22nd. Venus moves easterly on the 23rd.

November 23–24: Regulus, Leo's bright star, is the fulcrum of the moon's position from night to night. Look up in the east after 10:00 P.M. Last-quarter moon is at 11:50 A.M., EST, on the 24th.

November 27–28: The crescent moon is in the morning sky on both days: above Virgo's bright star Spica on the 27th; closer to the star on the 28th.

November 29–30: The moon passes Venus on the 29th and Mercury on the 30th, but all rise too late in the morning to be seen, even though Mercury is at its greatest elongation to the sun's right.

Editor's Note: The Sky Map in the October issue shows the evening constellations and stars for this month and gives the dates and times for use.

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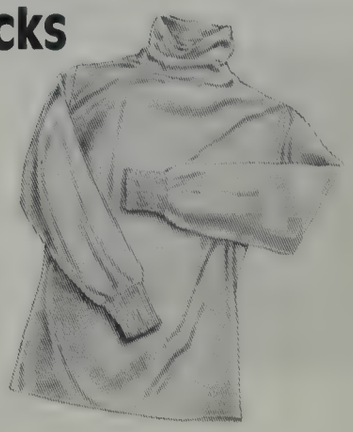

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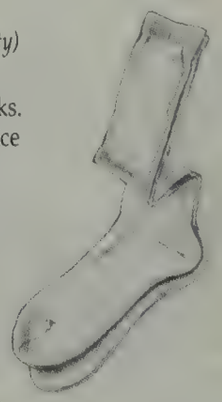

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How the North Was Won

by Barry Maine

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COMPANY OF ADVENTURERS, by Peter C. Newman. *Viking, $25.00; 413 pp., illus.*

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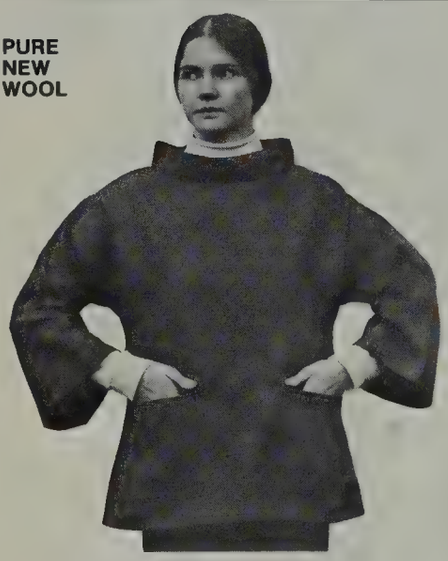

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the future of the Hudson's Bay Company and planted the seeds for a new nation. Nature was their greatest adversary. Technology during the eighteenth century had advanced only far enough to get men to where they wanted to go, so long as it wasn't too far north or south. Once they got there they had only their will to survive to fall back on. This is the story of ship surgeons amputating frozen fingers and toes, of traders waiting out ten months of bitter cold for the annual return of supply ships from England, and of explorers chewing on deer hide to put off starvation and resorting, at the last, to cannibalism.

Europeans first laid eyes on the region en route to what they hoped would be a northwest passage to the rich trading lands of the Far East. One of the first was Henry Hudson, for whom the bay is named, who perished there in the icy waters his mutinous crew consigned him to—an inauspicious beginning. A half century later Prince Rupert of the Rhine, cousin to Charles II, was granted a royal charter proclaiming him and his followers "true lords and proprietors" of all the lands bordering on Hudson Bay. This was granted not for the purpose of settlement but rather for the exclusive purpose of trading utilitarian goods—knives, axes, muskets, copper kettles, and so on—to the native Indians in return for beaver furs. Unlike the French to the south, they sought to convert the Indians to capitalism, not Christianity.

Beaver fur was in high demand in Europe throughout the eighteenth and well into the nineteenth century. An entire civilization was debauched in the service of fashion a hemisphere away. Newman is quick to point out, however, that the Indians saw themselves as partners in an enterprise that benefited them as well. They took in a windfall of trade goods in return for what they regarded as a worthless animal in plentiful supply. They also proved to be shrewd traders. There was mutual exploitation, although over the long haul the Indians gave up far more than they realized: their independence and self-sufficiency, their spiritual relationship to the land and the animals they depended on for survival, and eventually their very lives to disease. Newman has reconstructed this unauthorized history of the Hudson's Bay Company from some sixty-eight tons worth of official company minutes, records, and papers, which included ship captains' logs, explorers' diaries, and daily journals kept by company officers in the field, called factors. The journals and diaries supply not only authenticity but much of the drama with entries that detail deprivation and depravity among the whites,

ıtal treatment of women among the In-
ans, and sexual commerce between the
vo cultures. They also help to explain
hy a five-year hitch on Hudson Bay often
ırned into a lifetime service for many
aders and company employees who re-
ırned home to England only to rush back
a primitive and near savage existence.
hanged by months and years of white
lence and solitude, and spoiled by the
xual freedom they enjoyed with Indian
aidens who were offered freely and ac-
epted gratefully as bed warmers, they
ad discovered in a frozen land what Jo-
eph Conrad's Kurtz had found in an Afri-
an jungle. It held them there.

As for the company, it had the good
ortune (Newman calls it plain luck) to
ttract adventurers such as Pierre
adisson and Samuel Hearne to establish
nd expand the fur trade in North Amer-
a and financial managers such as John
hurchill, duke of Marlborough (ancestor
f Sir Winston), and Sir Bibye Lake for
ach fiscal crisis at the home office. The
ompany risked little, conceding outposts
nd forts to the French whenever discre-
ion proved the better part of valor and
xploring the interior only when forced to
y French competition. (Newman be-
ieves its motto should have been "Wait
nd Seize.") It was circumspect by policy,
oping to avoid the public scrutiny and
riticism that proved the ruin of other
hartered companies, such as the East In-
dia Company.

Newman clearly loves the adventurous
more than the business side of his subject
(and who can blame him?). The names of
company governors and records of annual
dividends are placed with the biblio-
graphic information in the appendixes.
Nothing but the hardship of physical pri-
vation is allowed to impede the progress of
manifest destiny in the narrative. The
story he tells is unique not only among
company histories but among histories of
North America as well. These European
adventurers never thought of themselves
as settlers or colonists; they were foreign
traders "perched on the desolate perime-
ter of Hudson Bay" in the service of absen-
tee landlords. Company decisions actually
determined the geographical boundaries
of present-day Canada; yet the company
did not move its headquarters there until
1970, three hundred years from the date
of its charter.

Barry Maine, an assistant professor of English at Wake Forest University in North Carolina, came across Company of Adventurers *in his research for a book he is writing on narrative strategies in histories of North America.*

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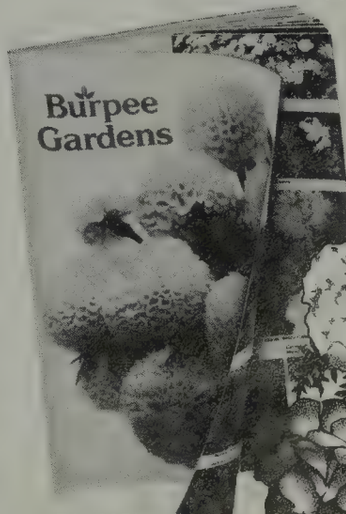

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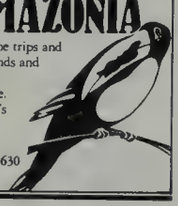

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Riddle of the Ridleys

Frozen and stranded, were these rarest of sea turtles giving a clue to their secret migrations?

by Anne Barkau Meylan

Twelve years studying sea turtles in southern climes had not prepared me for a December day on a windswept beach along New York's Long Island Sound. Along with rescue teams from the Okeanos Ocean Research Foundation, I was scouting the beaches near Riverhead, Long Island, in search of beached sea turtles stunned by the unusually cold weather. The windchill factor made it feel like minus fifteen degrees. Swaddled in down parkas, wool scarves covering all but our eyes, we plodded against the wind down stretches of rocky shore, where high water prevented our jeep's passage. Every few hundred yards, we found what we had come for—still and sometimes lifeless forms in the piles of storm wrack at the high-tide line. These were Kemp's ridleys, the most endangered of all sea turtles, and a species only rarely recorded in New York waters. If I hadn't seen the turtles myself, I would have thought there had been some mistake in their identification. Even within the ridley's primary range of the Gulf of Mexico, sightings are uncommon these days, and the precipitous decline in the number of females arriving at the turtles' nesting beach has demographers wondering just how many more years Kemp's ridley will be with us. The beaching of dozens of these turtles in Long Island Sound last December made an arresting find.

Before the day was over, our rescue team took seven ice-cold ridleys back to the house of Okeanos director Sam Sadove, where they joined others in a makeshift "warm-up room." Most of the turtles we picked up had suffered too much from the cold to recover or were already dead when found. Eighteen were still alive and responded well to gradua warming in kiddie pools that Sam and his wife, Gill, had added to the furnishings o the small house in Jamesport. That night the enthusiastic pounding of turtle flippers splashed salt water all over the walls and kept us wide awake. Outside the temperature went down to the midteens, and in the marina next door the water froze.

For the next several weeks, stranded turtles continued to appear along the eastern two-thirds of Long Island's north shore. By mid-March, forty-four ridleys, two green turtles, and ten loggerheads had been picked up by Okeanos, the agency charged by New York State to handle strandings of both sea turtles and marine mammals. Another five or six turtles were reported but could not be recovered. Because several of the strandings occurred in seldom-traveled marshes, we assume that

Turtle Travels

Where do Kemp's ridleys go after leaving their nesting beach in Mexico? Records of sightings and strandings suggest these rarest of sea turtles may follow major ocean currents out into the Atlantic where they will mature, eventually returning to the Gulf of Mexico to breed.

Joe LeMonnier

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other stunned sea turtles went unnoticed. Cold-stunning events involving sea turtles are not unprecedented, having occurred in Florida in 1894/95, in 1977, 1981, and 1985, but Kemp's ridley was never the primary victim.

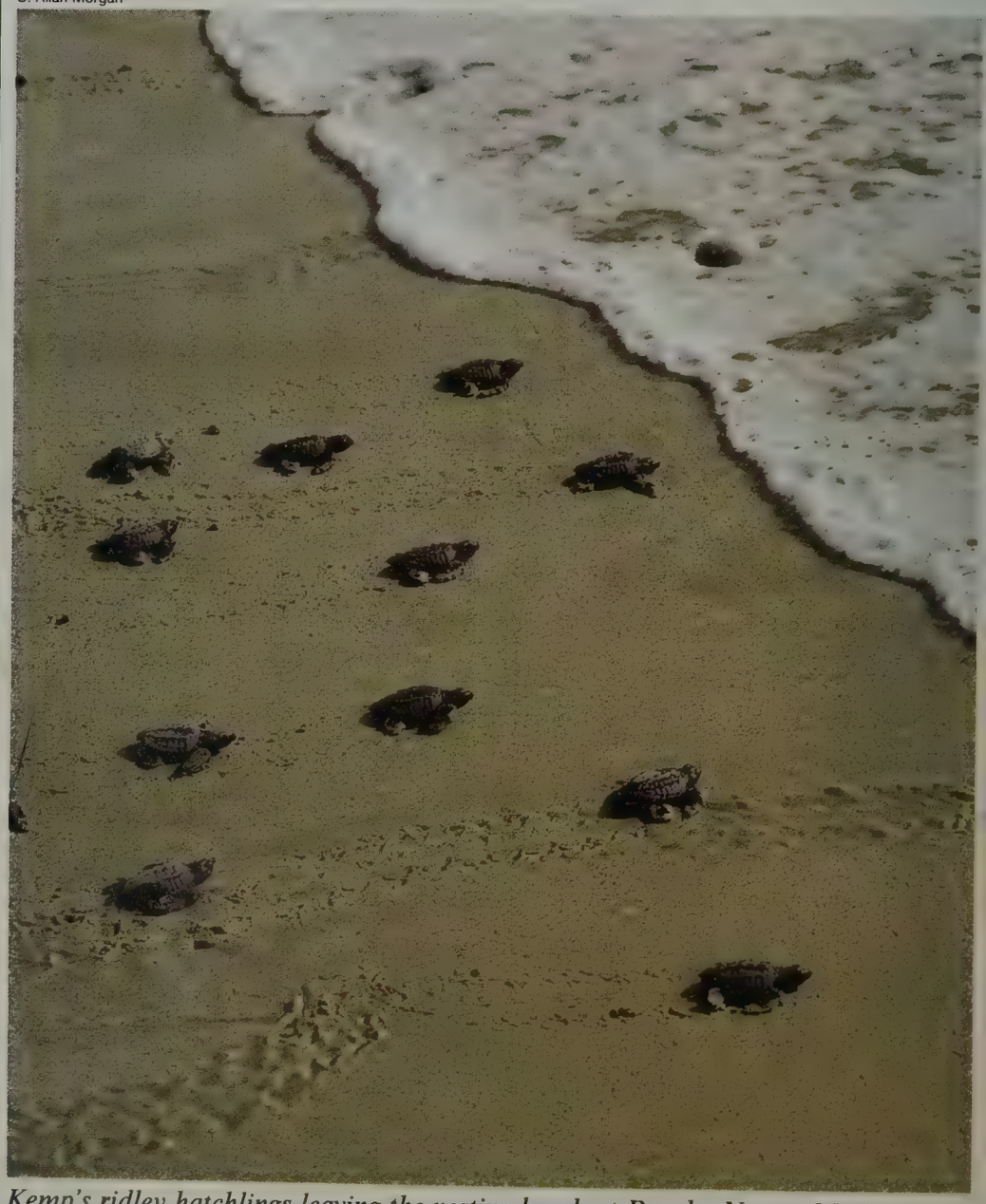
Seven of the turtles that survived the ordeal were flown south and released in the Florida Keys under the supervision of the National Marine Fisheries Service. All were tagged with numbered metal bands bearing a return address, but so far no recaptures or sightings have been made. Thirty-five dead turtles, most of them ridleys, were donated by Okeanos to the Herpetology Department of the American Museum of Natural History, where they will be a source of scientific data.

There seems little doubt that the extreme cold was responsible for the strandings. Three different species were similarly affected soon after the onset of the severe weather. Nearly all of the eighteen turtles found alive responded well to gradual warming—some making swift and complete recoveries. Necropsies conducted on the turtles by Okeanos revealed no signs of injury or exposure to toxins.

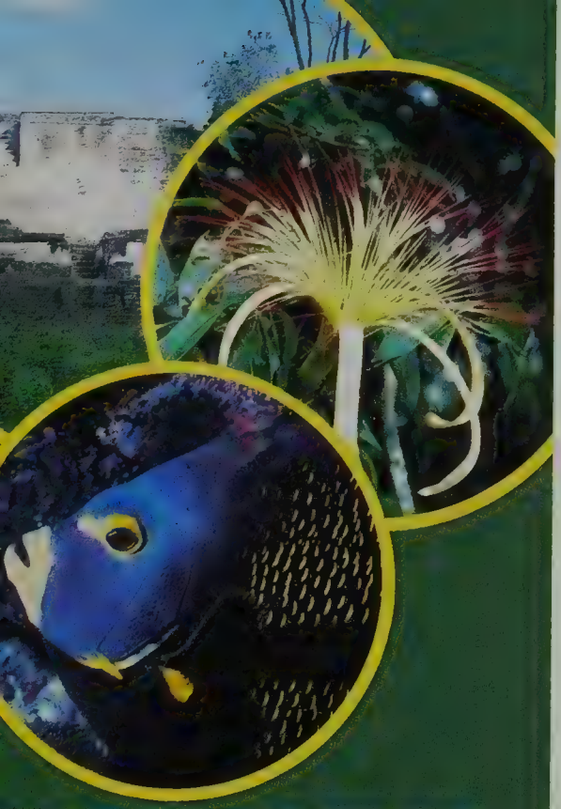
This cold-stunning episode was only the latest in a series of riddles the ridley has presented to the world. First described by Samuel Garman in 1880, Kemp's ridley (*Lepidochelys kempi*) was not widely recognized as a distinct species of sea turtle until the 1940s. It was chronically confused with its close relative, the olive ridley (*L. olivacea*), and with the loggerhead turtle (*Caretta caretta*). To this day, improperly labeled museum specimens are commonplace.

In the 1950s the ridley's riddle concerned its ancestry. Many biologists regarded it as a hybrid, the result of a cross between a loggerhead and a green turtle. No one had ever seen ridleys mating or knew where they nested. Fishermen in the Florida Keys were familiar with ridleys because they caught them in their nets, but they were convinced that the turtles were sterile. Herpetologist Archie Carr of the University of Florida interviewed

C. Allan Morgan



Kemp's ridley hatchlings leaving the nesting beach at Rancho Nuevo, Mexico



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ores of fishermen about ridleys."This re ridley don't have no young 'uns," he as told, "He's at the end of the line, like a ule." Many of Carr's early years were ent searching tropical beaches for the reeding ground of the enigmatic Kemp's dley.

Only in 1961 did the scientific world arn the ridley's well-kept secret. A pri-ate film made in 1947 by a Mexican ngineer, Andres Herrera, showed thou-ands of Kemp's ridleys emerging on a nely stretch of shore in the state of Ta-naulipas, Mexico, some 200 miles south f Brownsville, Texas. The site bears the ame of a nearby town, Rancho Nuevo. Thorough exploration of Gulf and Carib-ean shores by sea turtle biologists for the ast twenty-five years has failed to reveal ny other sites of concentrated nesting. Ninety-five percent of the population of esting females comes to this seventeen-nile strip of beach, with the remainder esting in the neighboring state of Vera-cruz. In its virtual allegiance to a single reeding locality, Kemp's ridley is unlike ny other sea turtle in the world.

From April to August each year, Kemp's ridleys aggregate and mate off he nesting beach at Rancho Nuevo. While the reproductive cycles of most ther sea turtles are longer than a year, many adult female ridleys appear to be on an annual timetable. Some females may emerge on the beach to nest several times in one season. An average clutch consists of 110 eggs. Males, present in the waters off the nesting beach, do not leave the water.

Herrera had the luck to film an *arribada*, or arrival. These mass nesting emergences had previously been docu-mented only for the olive ridley, a species particularly common along the Pacific coasts of Mexico and Central America. The *arribada* appears to be a behavior unique to the genus *Lepidochelys*, and the *arribadas* of olive ridleys are considered one of the wonders of the world. Between 50,000 and 150,000 turtles emerge over six or seven nights to lay their eggs at Nancite on the Pacific coast of Costa Rica.

Calculations based on Herrera's film placed the number of Kemp's ridleys nest-ing at Rancho Nuevo in 1947 at 40,000. By 1966, when the Mexican government installed its first camps on the beach to monitor and protect turtles, the *arribadas* had shrunk to only 2,000 turtles, a decline of 95 percent. The apparent cause for the decline was excessive egg harvesting by local *hueveros* (egg takers), combined with predation by coyotes and erosion of nests by storm tides. A joint conservation

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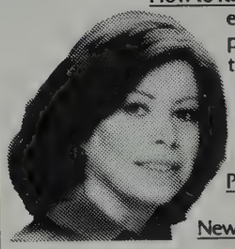

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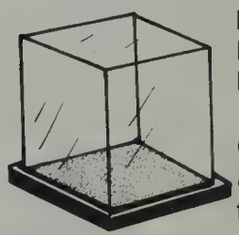

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effort was launched by Mexican and U.S. government agencies in 1978, but the number of females arriving at Rancho Nuevo continues to decline. For the last eight years, an estimated 500 to 750 females per year come to nest. Egg poaching has been virtually eliminated, but a relatively new problem, incidental capture (and drowning) in shrimp nets, threatens to deliver the *coup de grâce*. Shrimp trawlers take a heavy toll of male and female turtles both off the nesting ground and on the feeding ground to which the ridleys disperse after nesting.

Recaptures of tagged individuals show two principal foraging areas for the adults: off the coast of Louisiana (from Marsh Island to the Mississippi Delta) and in the waters off the Tabasco-Campeche area of Mexico (Tupilco, Tabasco to Champotón, Campeche). It is no accident that shrimp trawlers and ridleys come together in these places. Ridleys feed primarily on crabs that share the habitat of white, pink, and brown *Penaeus* shrimp. Portunid crabs (*Callinectes, Ovalipes*) seem to be favorite prey, but clams, mussels, and snails are also eaten.

We know far less about the whereabouts of young ridleys. If ridleys follow the generalized life history hypothesized for other sea turtles, we can expect that they live in different places at different times in their lives. Hatchlings leave the nesting beach and travel into the open ocean where they take up a pelagic existence among weed- and drift-lines that form along the edges of major current systems. For some species this period may last several years. It is followed by entry into coastal areas. At some of these areas one finds young turtles almost exclusively. Once mature, turtles move on to either a permanent feeding ground or a series of feeding grounds through which they routinely travel. Except for migrations to the nesting beach, the rest of the turtle's life is spent in these feeding areas.

The degree to which Kemp's ridley conforms to this general life history is not known. We do know that ridleys of all sizes are found in the Gulf of Mexico, and it is possible that they spend their entire life there. An important developmental habitat for subadult ridleys was discovered in the 1950s on the west coast of Florida at Cedar Key. Since then, other sites where young ridleys routinely appear have been found in the Gulf of Mexico from Texas to Florida.

Ridleys are regularly seen in several places along the eastern seaboard of the United States as far north as Cape Cod, Massachusetts. This contingent of the population, which is practically all juveniles, has been the subject of contro for decades, because great distanc contrary currents would appear to m impossible for these turtles ever to r to the nesting beach at Rancho N Those who believe these turtles are l the population point out that many p in northern waters at the onset of weather, and those that survive ha clear way to follow currents back t Gulf of Mexico. Despite thorough se ing by sea turtle biologists, ridleys a known in the Bahamas or the Greate Lesser Antilles, through which they v have to pass on their way back to the of Mexico from the Atlantic.

Following the Long Island cold ning episode, a review of both publ and unpublished records of ridley ings along the Atlantic coast conv me that the actual number of ridleys the coast may be far higher than people now suspect. The National M Fisheries Service reports that 77 ou total of 273 ridleys (29 percent) stranded in the Gulf and off the soutl ern states of the United States bet 1980 and 1985 were recovered in th lantic. Ridleys are routinely caug shrimp trawls that operate in the around Cape Canaveral, Florida. D the period from 1979 to 1985, 68 Ke ridleys were recorded in Chesapeak by the Virginia Institute of Marine ence, and scientists there project a sonal population of 200 to 300 indivi The ridley is the most common spec marine turtle recorded at the We Bay Wildlife Sanctuary at Cape Massachusetts. At a recent meeti was reported that 88 ridleys were fou that area from 1976 to 1985.

Before last December, there were three published records of ridleys in Island Sound, and only eight for the state of New York. This spotty reco ridleys may be more a case of poor r keeping than a true lack of ridleys. the 1985 cold-stunning event, mor ports of New York ridley sightings previous years have come in. Specim the American Museum of Natural tory and in private collections docu the occurrence of ridleys at one Lo land beach alone in at least three diff years: 1957, 1983, and 1985. Were along with the others stranded last w merely ill-fated waifs swept out of normal range in the Gulf of Mexico? Long Island another station on the tu regular migratory route? How does "lost" east coast population fit int ridley enigma?

The Gulf Stream flows north alon eastern seaboard of the United State

could easily pick up animals that have left the Gulf of Mexico through the Straits of Florida. Archie Carr has suggested that once the turtles reach northern waters, meandering eddies of the current deliver them right to the coast. When these eddies split off, they carry with them whatever animals are in the warm water of the main current. The sporadic occurrence of tropical fish in inlets along the south shore of Long Island is well known and often attributed to this phenomenon. Such transport of ridleys by the Gulf Stream could occur whether they were migrants or waifs.

We know that over the short term ridleys are perfectly capable of living in the bays along the eastern seaboard. The turtles that were found in Long Island Sound in 1985 appeared to be in remarkably healthy condition. They were juveniles, as are practically all those found along the eastern seaboard, and remarkably similar in shell size, averaging some eleven inches. Possibly they were part of a single age class or even a single "fleet" that traveled together from some distant place. Olive ridleys are known to travel in groups, and in the 1930s a group of Kemp's ridleys, described by an observer as a fleet, was seen traveling from Buzzards Bay into Vineyard Sound, Massachusetts.

The observations that almost all the ridleys along the eastern seaboard are immature, that they are in healthy condition and willing to eat, and that at least some of them are traveling in groups support the idea that the east coast is part of the normal range of ridley migration.

The theory that ridleys along the eastern seaboard are accidental strays is supported by the record of strandings of small, usually cold-benumbed ridleys on the opposite side of the Atlantic—in Scotland, Wales, England, the Channel Islands, the Netherlands, France, the Azores, and Madeira. The strandings are most numerous in late fall months, with a peak in December.

From controlled tolerance tests, we know that Kemp's ridleys become sluggish and float at temperatures below 13°C; small ones succumb at 5°C. Thus, those in the northeastern United States must either hibernate or leave the area during the winter months. Although loggerheads, green turtles, and possibly ridleys overwinter by burrowing into the mud at more southern latitudes, there is no evidence to date that any sea turtles overwinter in colder northeast waters. There are other turtles that do, however, such as the diamondback terrapin, which hibernates in some of the same areas where ridleys have been found.

Ridleys along the eastern seaboard may simply retreat to southern waters of the United States during the winter. A small number of recaptures of tagged individuals supports this theory. Some of the loggerheads that nest on beaches in the southeastern United States follow such a pattern, with a seasonal advance into, and retreat from, northern waters. The route that loggerheads follow back south, and its relationship to currents, is unknown. One possibility is that they travel close to the coast in order to avoid the contrary Gulf Stream, but against-current migration is also possible and is well documented for adult loggerheads, as well as for adult green turtles.

A third possibility is that ridleys along the eastern seaboard eventually embark on a purposeful migration that takes them out into the Atlantic. By keeping to warm-water currents and eddy systems such as the Sargasso Sea, they may escape cold winter temperatures. Those that perish along the U.S. coast and on European shores each winter may be the unfortunate few that did not leave coastal waters in time or make it into appropriate current

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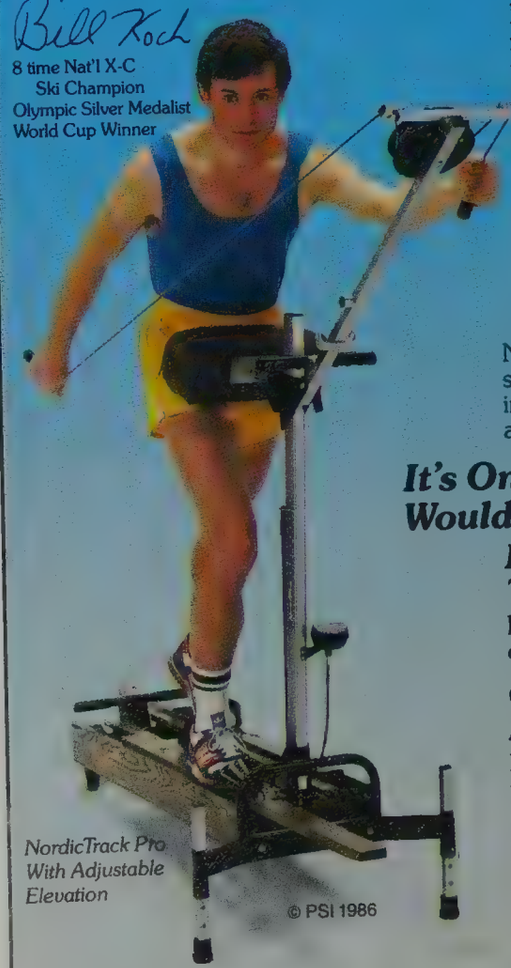

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systems. Archie Carr has recently suggested that young loggerheads that hatch on beaches in Florida, Georgia, and the Carolinas spend several years in the open Atlantic, perhaps making several transoceanic journeys before reentering coastal habitats. There are numerous open-sea sightings of loggerheads to support his theory. The lack of ridley sightings may be due to the perennial identification problem that plagues the species or to its much smaller population.

At what size and by what route young ridleys might leave the Atlantic Ocean on their return to Ranch Nuevo is open to speculation. Unknown in the Caribbean, the one place they do occur with some regularity is in the Florida Keys. With some against-current maneuverings, they may be able to work their way to the Keys and on into the Gulf of Mexico. Perha the nearly grown ridleys at Cedar Key, the west coast of Florida, have already ha their look at the world.

The Long Island cold-stunning episo invites new speculation. That there shou be forty-five young ridleys out there in a one place in the ocean today is a promisi sign. Judging from the size of the turtl recovered in New York, they most like hatched at Rancho Nuevo after the Mex can government began its program of pr tection in 1966. It may mean that we ca expect to see more young ridleys in th future and solve the mysteries of the migration.

Anne Barkau Meylan is an associate the Department of Herpetology at th American Museum of Natural History

At the American Museum

Water on Tap

New York City's water system is served by a complex system of reservoirs, aqueducts, and pipes. *On Tap: New York's Water Supply*, an exhibition opening Thursday, November 20, in the American Museum's Gallery 1, will examine the history, sources, and delivery of water to the city. Displays will include a fire hydrant, cut away to show its workings, and a model of a "riser," a device that brings water from tunnels hundreds of feet below the city to the mains that distribute it.

Mammoth Hunters

Using an array of props and illustrations, environmentalist-teacher Jack Branagan will re-create the environment of the Ice Age in *The Ice Age and Its Mammoth Hunters*. A 12-by-10-foot scrim will help Branagan create the illusion of a moving glacier, and he will use a puppet of a woolly mammoth as he relates the lives of these extinct creatures and the men that hunted them. This family program will cost $2 and is open only to members. Performances will take place on Sunday, November 23, at 1:30 and 3:30 P.M. in the Kaufmann Theater. For more information call (212) 873-1327.

Sexual Evolution

About two million years ago, the human conventions of marriage and the family began to develop. So says Helen Fisher, an associate in the Museum's Department of Anthropology and a regular guest on NBC's "Today" show. In *Of Human Bonding*, a free program open only to members, Fisher will discuss the changes that came when human beings first descended from the trees, women lost their period of heat, and men and women began to establish permanent mating patterns. *Of Human Bonding* will take place on Tuesday, November 18, at 7:30 P.M. in the Main Auditorium. For more information call (212) 873-1327.

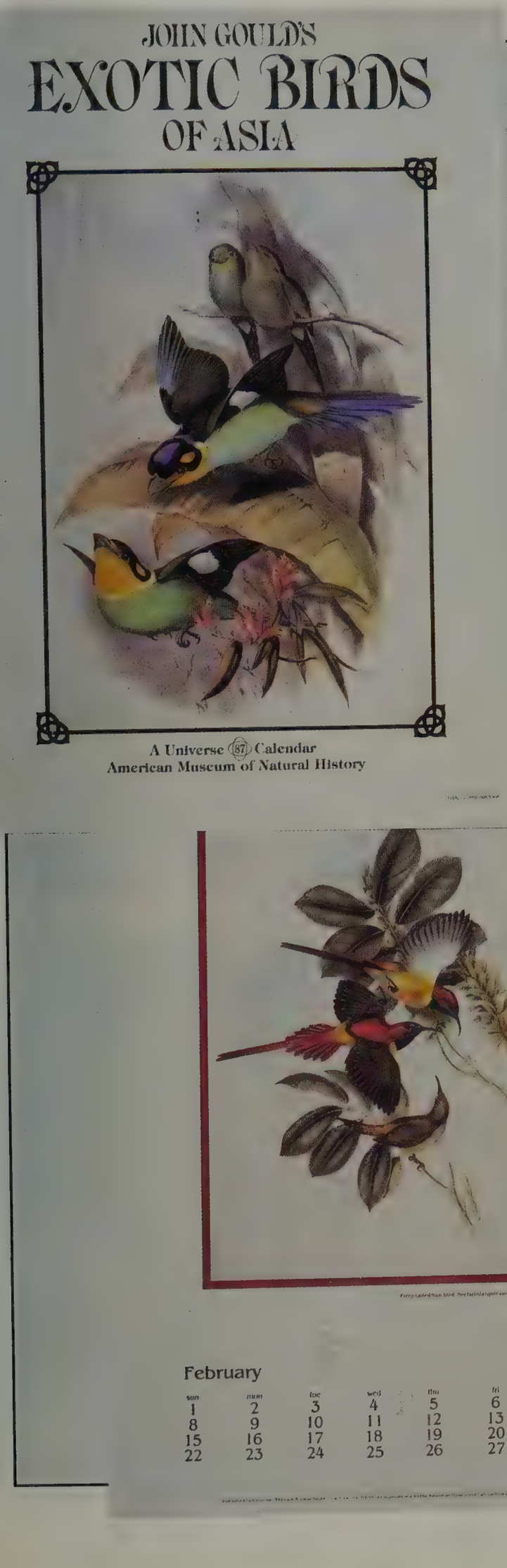
Puerto Rican Song

Repertorio Español, a New York-based theatrical company, will perform nineteenth- and twentieth-century Puerto Rican music in *Puerto Rico: Encanto y Cancion* (Puerto Rico Sings). Included will be more than forty popular and semiclassical songs by the island's most significant composers. *Puerto Rico Sings* will take place on Monday, November 17, at 7:30 P.M. in the Main Auditorium. Tickets are $5 for members and $6 for nonmembers. For more information call (212) 873-1300, ext. 514.

Caribbean Month

November is Caribbean Month in the Leonhardt People Center. Each weekend will be devoted to Caribbean music and dance, folklore, history, and culture. These free programs will take place from 1:00 to 4:30 P.M., and seating will be on a first-come, first-served basis. For a complete schedule of events call (212) 873-1300, ext. 514.

In conjunction with Caribbean Month, two films will be shown in the Kaufmann Theater. *Sugar Cane Alley*, about the coming of age of a boy in 1930s Martinique, may be seen on Sunday, November 2, at 1:00 and 3:30 P.M. *The Harder They Come*, starring Jamaican reggae artist Jimmy Cliff as a country musician who moves to the city in search of stardom, will be screened on Saturday, November 22, at 1:00 and 3:30 P.M. Both films are free with Museum admission.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Members' Book Program

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Hold the Caviar

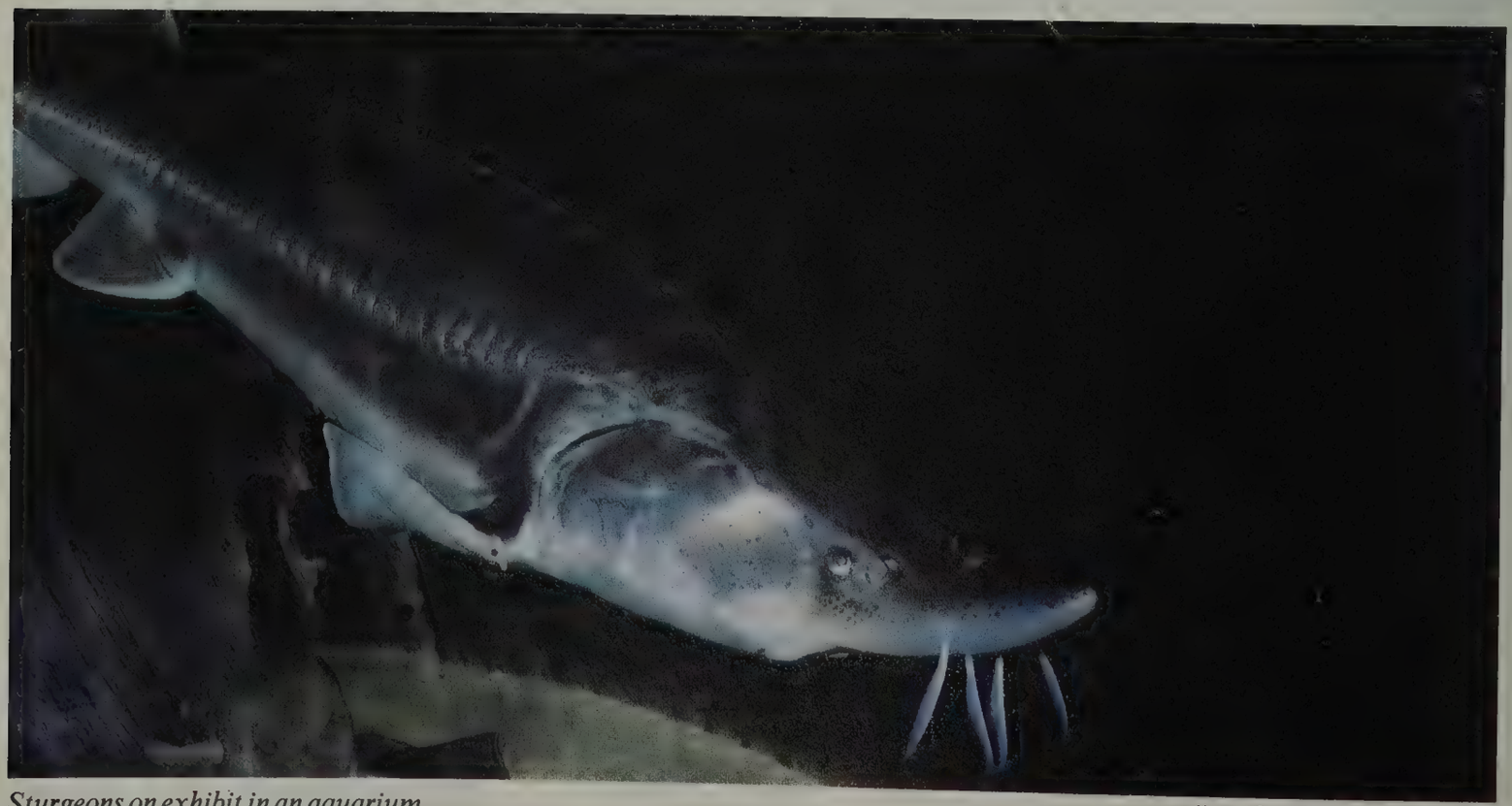
There is more to the sturgeon than its roe

by Raymond Sokolov

Once upon a cold morning, I found myself wading through the icemelt at the Fulton Fish Market on the lower east side of Manhattan. The market was a vigorous, ugly, loud place, full of roughnecks and big fish lying out under the dilapidated old pavilion roofs. Even now, after the rest of the neighborhood has been spiffed up and yuppified by the Rouse Corporation's South Street Seaport project, the market maintains its wonderfully dubious character. I suppose I would feel less romantic about the place if I had to do regular business there and contend with the cacophony and moist, moldering mess. But on that morning fifteen years ago when I first blundered into the market, I was dazzled by the big halibut displayed cheek by gill and the dozens of species I couldn't identify at all. The fishmongers mostly ignored me, recognizing an unprofitable retail customer. But after I had spent half an hour or so prowling and dodging the loaded hand trucks pushed by men shouting, "Watch your back," I heard a fellow in an apron call out, "Wanna buy a sturgeon?"

I looked around to locate the voice in the general din. The man was definitely looking at me. And on a platform in front of his knees lay the largest fish I had ever seen. I didn't measure it, but it must have been more than five feet long, with an elongated nose and bony bumps along its back and side. I wish I could say I had taken that sturgeon home. I would then have joined an elite tradition of people associated with abnormally large fish. The great original in this line was Crispinus, target of Juvenal's fourth satire, "a monster redeemed from his vices by no virtue" who bought a monster turbot. In gourmet circles, the story still circulates of a French noble household forever shamed by a gift fish too large for the lord's largest platter. And then there was the royal banquet at which the major domo proudly presented a great salmon to the assembled guests but dropped it on the floor. Humiliated, he gathered up the fish and took it away—only to return with a second fish even larger than the first. It had all been planned, of course.

In England, sturgeons belong by law to the crown (as do whales). But it is in Russia that the sturgeon truly gets the respect it deserves, as the largest freshwater fish on the planet and a magnificently delicious source of flesh. I am confining this discussion to flesh and avoiding the stur-



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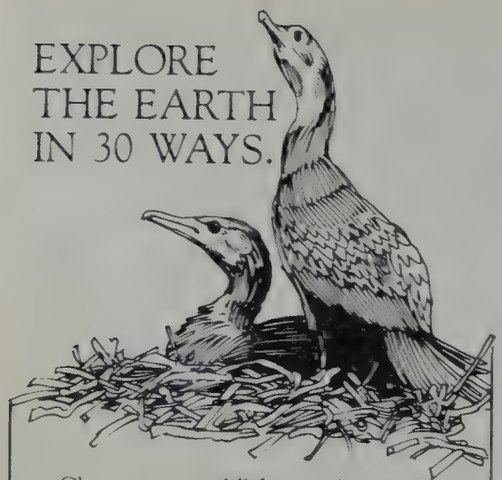

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geon's most obvious claim to fame, its gray-black roe. Caviar is another subject for another time, which the impatient can pursue in Susan Friedland's exhaustive and elegant new book, *Caviar* (Scribners). Caviar needs such intelligent explanation but it does not require further promotion in a world gone caviar mad. In fact the demand for caviar has endangered the survival of the sturgeon itself.

And yet this noblest of fish survives and even flourishes. The attentive newspaper reader will have noticed a profusion of articles appearing over the last year or so testifying to the resurgence of this primordial survivor from the evolutionary dawn of bony fishes more than 100 million years ago. Connoisseurs of sturgeon news took delighted notice last April when an official fisheries report from the Soviet Union announced that the crew of the trawler *Pioneer* had made an "amazing" catch in the Black Sea off the Bulgarian coast: a 150-year-old sturgeon more than sixteen feet in length, weighing nearly 1,400 pounds. (This monster is still far from the largest sturgeon reported from pre-revolutionary days: twenty-eight feet and 2,800 pounds.)

Members of the sturgeon family, the Acipenseridae, are found in all kinds of water around the world, salt and fresh. They are anadromous, swimming inland and upriver to spawn, waxing fat as adults in marine habitats or in lakes. There are, for instance, sturgeon in Wisconsin's Lake Winnebago that spawn fifty miles upstream in the Wolf River, dropping a million and a half eggs on the rocks, under the watchful eye of volunteer sturgeon guards protecting these big, ugly, half-blind fish from poachers hoping to spear them for the black market. Fines in Wisconsin for sturgeon poaching begin at just under $3,000, which, along with the human surveillance of spawning grounds, has reduced human predation and allowed the population of fish in Lake Winnebago longer than forty-five inches to surpass 75,000.

This is a good sign for American sturgeon fanciers who may hope for the return of the day when this country had an important sturgeon industry. The "meat" was so common in New York State that, as I read in Alan Davidson's *North Atlantic Sea Food*, it was called Albany beef. The Delaware was so full of sturgeon in colonial times that settlers wrote home about them. But by the end of the nineteenth century, sturgeon had declined seriously, and by now we on the Atlantic seaboard have little left of those days except the slang of the old-time sturgeon fisheries: mammoses were sturgeon young, cows

re females with hard roe, runners had t spawn running out of them, and nkers had already spawned. Males re called bucks.

The major domestic sturgeon market is v Seattle, where three times a year sh sturgeon from the rivers of the Pac Northwest (*Acipenser transmontus*, the white sturgeon, and *A. diostris*, the smaller green sturgeon) ow up at the Pike Place Market. Convation, combined with a revival of nerican caviar production, is definitely nging back native sturgeon. But our al industry is still insignificant, comred with the world's sturgeon paradise,

Eigeland; Black Star

isherman stack a catch of sturgeon from e Caspian Sea.

e Caspian Sea. We are not talking bouque sturgeon here. We're talking beluga, e biggest and most prized of all sturgeons. Soviet sources boast that the Caspin's beluga population exceeds fifteen illion fish, a rich potential for caviar xport and for earning hard currency. Soet authorities have also been paying ose attention to corruption in this lucrave industry. Earlier this year, after largecale examples of sturgeon and caviar neft were uncovered at the Zhdanov Fish Combine and at various fishing collective arms, Zhdanov city prosecutor N.A. Gorlov was fired and criminal charges ere brought against V.G. Vlaslov, a poce official in charge of protecting the Sea f Azov's fish reserves, and one V.A. Semyonov, an inspector of the Departnent for Combating the Embezzlement f Socialist Property and Speculation.

Chinese authorities have also been doing their part for sturgeon survival. Ichthyologists in Hubei Province have been

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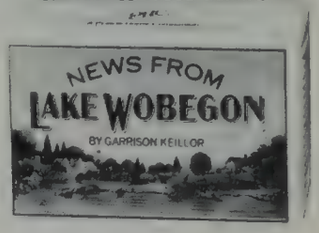

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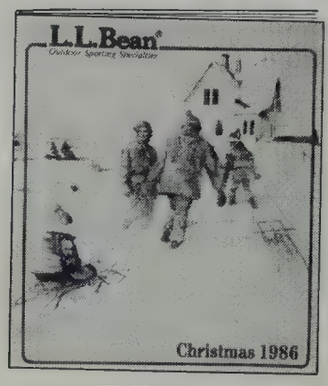

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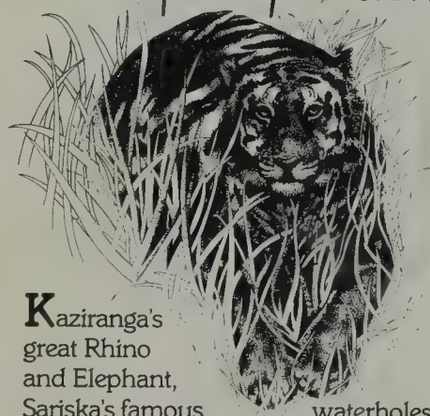

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hard at work helping the rare Chinese sturgeon bounce back from a damaging period of interference with its anadromous migrations that was caused by the construction of the Gezhouba Dam in the Yangtze. By the latest account published by the official Xinhua News Agency, 350,000 sturgeon fry had been incubated at Yichang and 100,000 of them had been released into the mighty Yangtze. If all this Marxist-Leninist solicitude for sturgeon continues to succeed, it will have two results, both of them salubrious for the sturiophile. The communist world will continue to produce the most aristocratic food for the most capitalist of reasons—the accumulation of investable wealth via caviar sales. And more important from my point of view, the net supply of sturgeon in the world will greatly increase.

I did finally manage to taste sturgeon a few years ago. I ordered it at the Café des Artistes in Manhattan but then was certain I had had my order switched in the kitchen. Someone must have sent out veal. When I gingerly inquired, the restaurant's owner, George Lang, explained that sturgeon tastes and even looks like expensive white veal. I was not the first to confuse the two. Medieval recipes for "sturgeon" sometimes turn out to be mock sturgeon dishes actually made from veal. For example, the fourteenth-century English manuscript *Goud Kokery* explains how "to make sturgyn" by taking veal and calves' feet and "seething" them in honey. The French classic culinary manuscript of the same period, *Le Viandier de Taillevent*, contains a recipe for "Esturgon de Chair," for which calves' head and feet are stewed in wine and vinegar.

I am not prepared to explain the similarity in taste between sturgeon and veal, which is so remarkable and unlikely as to be spooky. But the sturgeon's unfishlike texture clearly owes something to the sturgeon's special biology. Transitional between the boneless and the bony fish, *Acipenser* has a cartilaginous notochord in place of a bony spine, and it lacks the internal bones of a normal skeleton. The flesh is therefore smoother and "meatier." It is also wonderfully pure and clean-seeming, despite the sturgeon's vacuum-cleaner life style as a toothless, sucking bottom feeder. Indeed, the word sturgeon itself derives from a German word, *stoeren*, that means to poke or scratch like a hen. But this should certainly not deter you from trying sturgeon smoked (the most easily available form) or fresh, if you find any. Escoffier turned his nose up at sturgeon flesh, finding it without much flavor ("*sans grande saveur*"). But I think you will disagree.

he most elaborate vocabulary of reci- is from the Russian tradition. Not long , after all, Moscow housewives could commonly seen bringing home stur- ns so large they had to be transported wo wagons hitched together. Perhaps greatest of traditional Russian dishes, t complex fish pie called *kulebiaka* or *libiac* is at its zenith when done with rgeon. Purists insist that no *coulibiac* uld be made without the gelatinous nal marrow of the sturgeon (*vesiga* in ssian). Not having tried it, I can't say, I do hope you will join me in hoping t our children will live in a world safe sturgeon—and that they will know ough to take advantage of their oppor- ity.

ymond Sokolov is a writer whose spe- l interests are the history and prepara- n of food.

Poached Sturgeon with Walnut Sauce

(Adapted from recipes in *The Art of Russian Cooking*, by Anne Volokh. Macmillan, 1983)

4 pounds sturgeon fillets
Salt
1 bottle dry white wine or champagne, or enough to cover the fish halfway
4 tablespoons unsalted butter, cut into ½-inch pieces
2 large lemons, cut into wedges and seeded
0 shelled walnuts
1 teaspoon Dijon mustard
2 hard-boiled egg yolks
1 teaspoon bread crumbs
1 tablespoon olive oil
1 tablespoon sugar
¼ cup wine vinegar or freshly squeezed lemon juice

. Cut the fillets into pieces about 3 inches long. Sprinkle lightly with salt and place on the rack of a fish poacher or in a chafing dish. Add enough wine to come halfway up the side of the fish. Dot the top of the fish with butter and arrange lemon wedges over the fish.
2. Cover, bring to a boil, lower heat and simmer until the fish is cooked, allowing 10 minutes for each inch of fish measured at its thickest point.
3. Meanwhile, chop the walnuts finely in a blender or food processor, turning the motor on and off to avoid turning the nuts into an oily paste. Add remaining ingredients and blend well. If sauce seems too thick, add 2 to 4 tablespoons boiling water.
4. Raise fish from poacher with rack (or from chafing dish with spatula) and let drain. Then remove to a warm platter and serve. Pass sauce separately.

Yield: 6 to 8 servings

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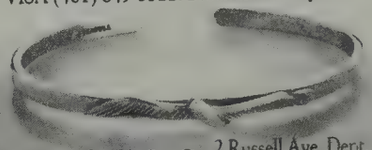

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Veronicella floridana grows to three inches and is the only species of its family found in the United States. Mark Deyrup, resident scientist at the Archbold Biological Station in Lake Placid, Florida, says this particular specimen made its presence known by eating half a lettuce plant in his home garden. An investigation turned up the culprit couchant amidst the litter where, though it shied away, it still kept its eyes on the photographer.

—*B.D.S.*

Photograph by Tom Eisner

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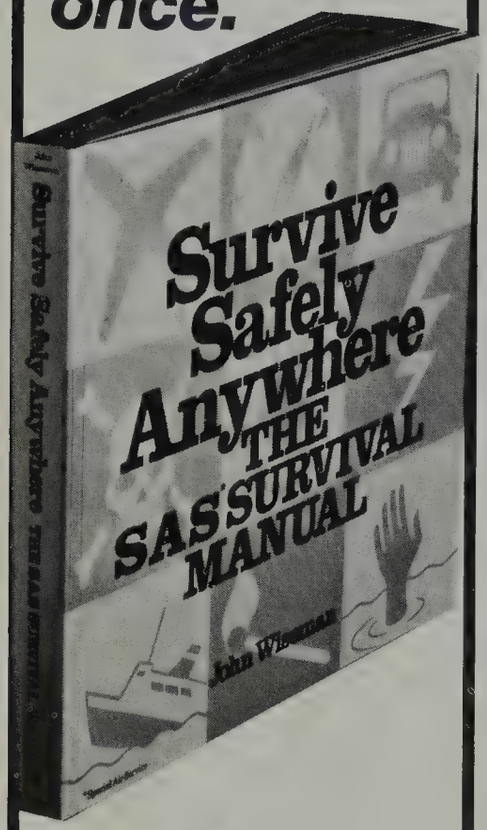

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Born in Oslo, Norway, **Knut R. Fladmark** (page 8) became concerned with when and where people first entered North America from Asia while he was a graduate student of archeology at the University of Calgary, in Canada. His principal fieldwork has been in British Columbia, including the Queen Charlotte Islands and sites on the Peace and Stikine rivers, Mount Edziza, and near Prince George. Fladmark is a professor of archeology at Simon Fraser University, Burnaby, British Columbia, where he has taught since 1972. For more detailed information related to his article in this issue, readers may refer to *Early Man in the New World*, edited by Richard Shutler, Jr. (Beverly Hills: Sage, 1983), which contains a chapter by Fladmark entitled "Times and Places: Environmental Correlates of Mid-to-Late Wisconsinan Human Population Expansion in North America." For a general description of Ice Age glaciation, see *Glacial and Quaternary Geology*, by Richard F. Flint (New York: John Wiley and Sons, 1977).

Robin Dunbar (page 40) is a senior research fellow in the Department of Zoology at the University of Liverpool, England. Dunbar (pictured above with his children) compares the pleasure he gets from living in remote places and trying to unravel complex animal societies with the enjoyment some people derive from crossword and jigsaw puzzles. To date, his scientific research has concentrated on primates and ungulates: gelada baboons (about which he has written a book, *Reproductive Decisions: An Economic Analysis of Gelada Baboon Social Strategies*, Princeton University Press, 1984), klipspringers (see *Natural History*, November 1985), and goats. Dunbar's curiosity about the wild goats of Rhum was sparked while he was pursuing the Walia ibex, a wild relative of the domestic goat, in the Ethiopian highlands. Interested readers might turn to George Schaller's 1978 book, *Mountain Monarchs: Wild Sheep and Goats of the Himalaya* (University of Chicago Press) and "Olympic Mountain Goats," by Michael Hutchins and Victoria Stevens (*Natural History*, January 1981).

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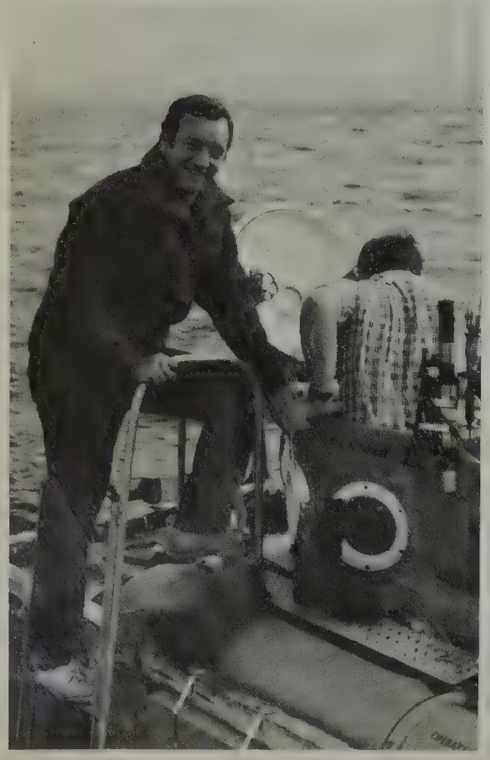
In the early 1970s the phenomenon of combative behavior in anemones and corals was being studied for the first time. **Kenneth P. Sebens** (page 48), then a graduate student at the University of Washington, began looking for evidence of fighting among anemones in his own study areas off the coast of Washington State. He not only found it there but also in anemones in Chile, Panama, the Caribbean, and the Gulf of Maine, where he conducted fieldwork while an associate professor of biology at Harvard. Now professor of biology and director of the Marine Science Center of Northeastern University, Seben's latest research concerns invertebrates that live in the ocean depths off the New England coast. For further information on anemone behavior he recommends *Marine Ecology*, by Jeffrey S. Levinton (Englewood Cliffs: Prentiss-Hall, Inc., 1982), *The Ecology of Rocky Coasts*, edited by P.G. Moore and Raymond Seed (Kent, England: Hodder and Soughton Educational Press, 1985), and his own article, "Agonistic Behavior in the Sea Anemone *Anthopleura xanthogrammica*" (*Biological Bulletin*, June 1984).



Born and educated in France, geologist **Paul Tapponnier** (page 56) is currently associated with the Institut de Physique du Globe, Laboratoire de Tectonic, Mécanique de la Lithosphère, at the Université Pierre et Marie Curie in Paris. He formerly worked at the Laboratoire de Géologie Structurale at the Université de Montpellier and in 1975 was a visiting research fellow at the Massachusetts Institute of Technology. Tapponnier has been on six scientific field trips to the Tibetan Plateau since 1980. **Kevin Kling**, whose photographs appear with Tapponnier's article, is his wife. For a further look at Tibet, readers might refer to *The Roof of the World*, by Zhang Mingtao and other members of the Multidisciplinary Research Team of the Qinghai-Tibet Plateau, Chinese Academy of Sciences (New York: Harry H. Abrams, Inc., 1982) and *New Views on an Old Planet: Continental Drift and the History of the Earth*, by Tjeerd H. van Andel (New York: Cambridge University Press, 1985).

The extremes of climate on the high deserts of the Rocky Mountains make demands on both the creatures that live there and the researchers who study them. **David Duvall** (page 66), who studies the rattlesnake in these inhospitable climes, believes he can observe there the most basic snake behaviors. With students Brent Graves, Mike King, Al Redder, and Matt Goode, and University of Colorado colleague David Chiszar, Duvall has begun to learn much of this snake's life history. An associate professor of zoology and physiology, Duvall (right), shown with Mike King, plans to begin comparing the migrations he has observed with those of other snake populations. For further reading on snakes he suggests *Rattlesnakes: Their Habits, Life Histories and Influence on Mankind*, by Laurence M. Klauber (Berkeley: University of California Press, 1982), *Their Blood Runs Cold*, by Whit Gibbons (University: University of Alabama Press, 1983), and *Snakes: A Natural History*, by H.W. Parker (Ithaca: Cornell University Press, 1977).

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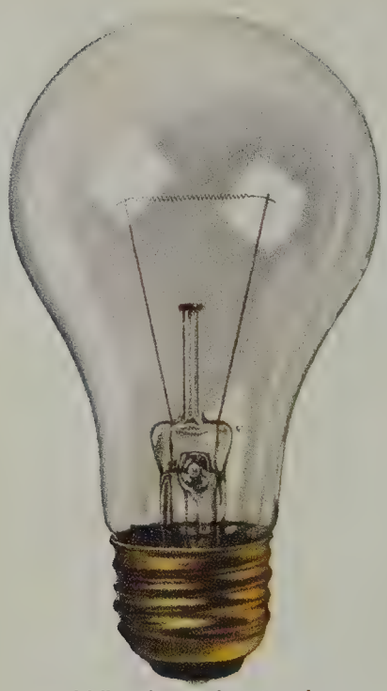

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Vol. 95, No. 12, December 1986
American Museum of Natural History, New York, N.Y.
Robert G. Goelet, President
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4 Possible Dogs *Pere Alberch*
Just how far can dog breeders go?

10 This View of Life *Stephen Jay Gould*
Glow, Big Glowworm

20 The First Americans *J. M. Adovasio and Ronald C. Carlisle*
Pennsylvania Pioneers

28 This Land *Robert H. Mohlenbrock*
Peralta Canyon, Arizona

34 Our Gang, Ostrich Style *Lewis M. Hurxthal*
On the African plains, particularly aggressive parents take over and raise as many as 100 chicks.

42 Natural Bonsai of Sunset Crater *Susan Mopper and Thomas Whitham*
Despite insect onslaughts and sex changes, the battered piñon pine remains the basis for an Arizona mountain ecosystem.

50 The Case of the Clannish Badger *Hans Kruuk*
The largest wild carnivore left in Great Britain is beloved but often misunderstood.

58 Night of the Radishes *Gary N. Ross, photographs by Serge Hambourg*
In Oaxaca City, Mexico, a lowly root vegetable reaches the heights of folk art for the holidays.

66 Hurricanes of the Arctic Night *Bruce Stutz*
Scientists have discovered what fishermen—those who survived—have known for centuries: that northern seas also have deadly hurricanes.

74 Reviews *Robert McC. Netting*
An Unfair Trade

81 The Living Museum
Fire Fountain at Pu'u O'o

84 Celestial Events *Thomas D. Nicholson*
Evening Holdovers

86 A Matter of Taste *Raymond Sokolov*
A Star Is Born

92 The Natural Moment *Photograph by Robert Caputo*
The Play's the Thing

94 Authors

Cover: *The world's largest bird, the flightless ostrich begins its life in a commune. Photograph by Kenneth Garrett. Story on page 34.*

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Possible Dogs

Lost toes or extra ones, one head or three—
it's all a matter of showing some constraint

by Pere Alberch

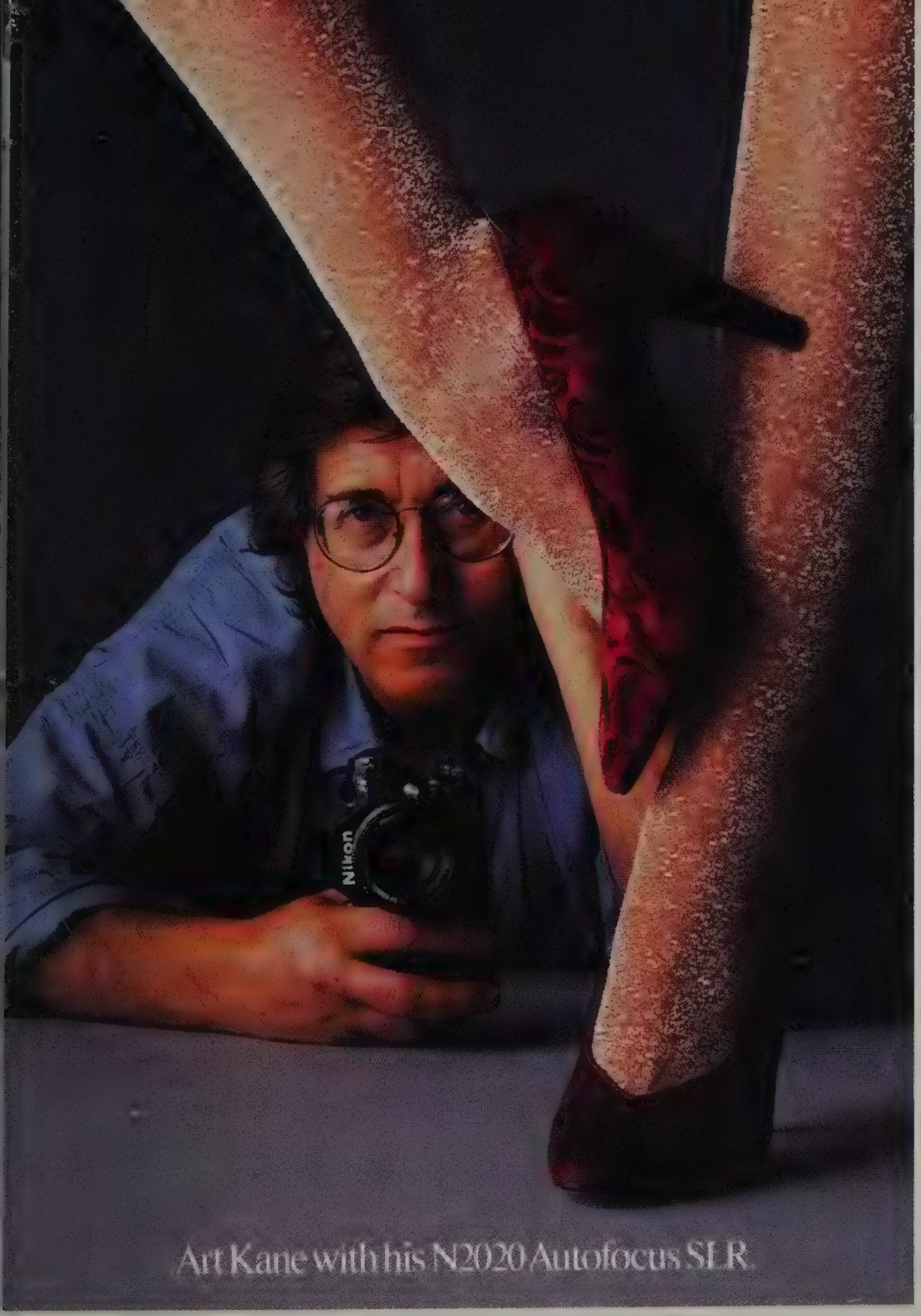
Henry Lee, a nineteenth-century British naturalist, claimed that one of the goals of zoology is "the intelligent appreciation of the perfect adaptation of the habits and structure of living animals to their modes of life." That this view is still predominant is exemplified by the many natural history articles that celebrate the ingenious ways in which specific features or behaviors enhance the survival of an animal or plant in its environment.

This perspective is rooted in the belief that natural selection determines the shape of the world around us. How many times have we gone to the zoo and when confronted with an unusual structure, say the trunk of an elephant, asked, What is it for? The underlying assumption is that if we know the function of a structure, we will also know the reason for its evolution. But claiming that something is adapted for a particular function is not a statement about its evolutionary origin. If animals and plants did not function satisfactorily in a particular environment, they would live somewhere else or have gone extinct.

As a biologist interested in the relationships between embryonic development and evolution, I focus less on problems of adaptation than on what limits, or constrains, the evolution of form. Rather than asking why plants and animals do what they do, I want to know why one particular

Domestic dogs range greatly in size

Elliott Erwitt; Magnum Photos, Inc.



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form evolves and not another that might seem just as suited, and in some cases better suited, for the purpose. For example, why do we have only two eyes and not four? Why only one head and not three? This aspect of evolutionary biology has, until recently, remained largely unexplored, since evolutionary biologists have traditionally focused on the issues of change and variation.

The morphology of an organism, that is, its form and structure, is the result of very complex physicochemical interactions that occur during embryonic development and that involve thousands of molecules. These interactions are endowed with their own properties, which depend on the laws of physics and chemistry. Recent discoveries in the field of molecular biology suggest that the genome is a highly organized structure. But even if genetic mutations were random (and thus could theoretically provide nearly limitless variation for natural selection to act on), the nature of developmental interactions causes certain forms to be easier to achieve than others.

To my surprise, it was while visiting my family in Spain that I chanced upon an especially simple and clear example of such developmentally constrained variation. I had just completed a series of experiments on the relationship between the number of cells in the early embryonic limb of salamanders and frogs and the number of toes that ultimately develop, and I was ready for some time off. When I arrived, my parents proudly showed me their new dog, a Great Pyrenees—a large St. Bernard-like breed used to guard sheep in the mountains of northern Spain and southern France. The dog was beautiful, but succumbing to my professional obsession with limbs, I immediately examined its feet.

I was pleasantly surprised to find that the animal had six toes on its hind feet, a fact that agreed with the hypothesis derived from my experiments. I had never seen a six-toed dog (not that I had looked at many dogs), and I assumed that my parents' pet was a mutant. Soon I was corrected by a friend, a dog breeder who pointed out that our dog was not a freak, but that, in fact, it exhibited the morphology required by the standards for the breed. My friend added, in what I considered an excellent example of adaptationist philosophy, that the extra toe—a condition referred to in the jargon of dog breeders as a double dewclaw—had been selected to improve the ability of these dogs to walk on deep snow.

So I decided to find out a little more about how the number of toes, or digits, varies among dogs. I learned that in most breeds, and in wolves and jackals, there are four digits on each hind limb and five (one being a short vestigial toe, or dewclaw) on the front limbs. Some breeds, most commonly the larger ones, also have dewclaws on the hind feet. In addition, some of the biggest breeds, such as Great Pyrenees, St. Bernards, and Newfoundlands, have a tendency to develop a sixth toe on their hind limbs. In most cases, breeders have ruled this an undesirable character and consistently select against it, but despite this strong, artificially imposed selective pressure, the character keeps reappearing. (As I mentioned above, the Great Pyrenees is an exception, in that the presence of an extra digit is standard for the breed.) Conversely, medium- and small-sized breeds rarely, if ever, develop this double dewclaw. In fact, very small dogs, such as Chihuahuas and Pekingese, have a tendency to lose the vestigial first digit on the front feet as well. (Incidentally, this claim that dwarfs lose digits more easily is also supported by the patterns encountered in frogs—a group of animals that I know better than dogs. The only frog species that have lost a toe are, in fact, among the smallest of all land vertebrates, with adult body sizes of about half an inch.)

Pedigree dogs are subject to selection pressures much greater than any to be encountered in a natural setting, and it is therefore difficult to come up with an adaptationist explanation for why the extra toes keep appearing in St. Bernards and why they so seldom crop up in the dwarf, or toy, breeds. My dog breeder friend, however, was not the only one to try. For example, in 1906, Charles W. Prentiss wrote a comprehensive review of known cases of both extra and lost digits in mammals. In his review, he claimed: "It is also noteworthy that the extra toe is most often found on the pes of the St. Bernard and Newfoundland, in which breeds it may be of some use for swimming and walking through deep snow."

I propose that an alternative explanation could be found if, instead of looking at the outer environment for answers, we focus on the inner mechanisms of limb development. A consideration of the developmental properties of embryonic limbs—based on my amphibian experiments, which were performed with the collaboration of Emily Gale—led me to predict that extra toes are indeed most likely to appear in large dogs, while digits are most apt to be lost in toy breeds. Note that this is a probabilistic argument. It does not require that all small dogs should lose toes or that all large dogs gain them but simply that there is a much higher chance of finding a big dog with six toes than a small one.

In our experiments with amphibians, we showed that if we treat the early embryonic limb—when, crudely put, it is little more than a sac of undifferentiated cells—with a chemical that stops cell division for a limited time, we can generate a limb that is about one-half the size of a normal one. The limb that develops with fewer cells is not only smaller, but it also often loses toes. The sequence of loss is highly specific, that is, certain bones are lost prior to others. In frogs for example, the first digit, or thumb, is always the first one to be affected by a reduction in the number of embryonic cells.

Jumping from frogs to dogs is admittedly a large, speculative leap. But the extrapolation is more justifiable if we consider one of the main features of development: once a mechanism evolves, it is used again and again in different contexts. This is true for limb development. With the exception of some minor differences, of interest only to the embryological connoisseur and which do not affect my hypothesis, mechanisms responsible for the patterning of the limb are qualitatively similar in all four-legged vertebrates.

I assume that large dogs have, on the average, relatively larger embryos and consequently larger limb buds (that is, composed of more cells). In principle, this hypothesis could be tested, but I do not think dog breeders would be very keen on the idea of slaughtering their prized pregnant females to measure the size of the embryonic limbs in the fetuses. (I take the opportunity to emphasize that this essay should be read as a theoretical exercise and that I do not plan to begin a massacre of pregnant dogs or to encourage anybody else to test these ideas.)

If my theory is correct, the reason dog breeders cannot eliminate the repeated appearance of an extra toe in, say, St. Bernards is that since they are selecting for large body size, they are also indirectly selecting for larger limb buds. Conversely, no matter how long breeders raised toy dogs in the snow, they would find it extremely difficult to select for extra digits in Pekingese and Chihuahuas, where there may simply not be enough cells in the developing limb buds to produce more than four toes.

Even if some individuals in a population of, say, Pekingese, had more limb-bud cells than were generally found in the breed, selection would not have much to act on. In principle, CAT scans of pregnant Pekingese could reveal which contained embryos with larger limb buds. Dog breeders could then choose to raise

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Hind foot of a Great Pyrenees, showing double dewclaw

and breed only those individuals. This scenario approaches science fiction, however. In a more realistic, natural setting, I believe selection cannot operate on such embryonic parameters as the number of primordial cells in the limb bud because the existing variation at the embryonic level (that is, the range in the number of cells) is not correlated with changes at the morphological level.

Clearly, there are other ways to gain or lose toes. A variety of mutations can affect other factors important in limb morphogenesis (such as changes in how much cells stick to each other and how much they move), and some of these mutations can result in changes in digit number irrespective of body size. Domestic cats, for example, are all more or less the same size, and yet individuals are occasionally seen with several extra toes per foot (see "Pussy Cat, Pussy Cat, Where Have You Been?" *Natural History*, July 1986).

But even though there are many ways to change the number of toes, doing so through changes in size may be the easiest one. A change in an embryonic property, say, how much embryonic cells adhere to each other, has been shown to have profound effects; such a change, however, is bound to result in a highly abnormal monstrosity. In contrast, an alteration in the number of embryonic cells is much more likely to result in a nonlethal mutation. This view is supported by the patterns of diversity found in the natural world: many morphological novelties, besides changes in digit number, tend to appear in concert with extreme dwarfism and gigantism.

With the possible exception of dog fanciers, most of us are not terribly concerned about the difficulty of obtaining a Chihuahua with a double dewclaw. Most people would be much more impressed with the powers of selection: that we can actually get a dog as small as the Chihuahua in the first place. But as fascinating, and sometimes bewildering, as the diversity of life in the world around us may be, we forget that the world could have been of a completely different shape. What about three-headed dogs, for example, such as Cerberus, the ferocious hound of Greek mythology that guarded the gates to Hades. This flesh-eating creature devoured whomever he caught trying to get out. Such an animal would undoubtedly be useful as a guard dog, but Cerberus is an impossible morphology; it cannot be generated by the existing developmental processes. (Why a three-headed morphology is difficult to obtain could be the subject of another article since there are good physical and biological reasons that preclude trifurcation of the body. Here it will suffice to resort to authority and empirical evidence. In the first comprehensive treatise of teratology—the science of monstrosities and malformations—Isidore Geoffroy Saint-Hilaire, a nineteenth-century French zoologist, pointed out that although two-headed monsters are relatively common, he never found a three-headed animal among the many malformed embryos he studied. I have not found any either.) Through years of careful selection, dog breeders have certainly produced an impressive variety of dogs, but they have always had to remain within the constraints of a given developmental program. There are neither Cerberuses nor six-toed Chihuahuas in our future.

All living beings are subject to certain constraints—gravity and the structure of the carbon atom, for example. Other constraints are specific to particular life forms. Even seemingly unimportant ones—such as the number of cells in the embryonic limbs of big and little dogs—can shed light on fundamental questions in evolution: How do we explain the order and diversity of form in the natural world? Why do we encounter only certain forms and not others? Two possible approaches to these questions are exemplified by the discussion between Marco Polo and the emperor Kublai Khan in Italo Calvino's *Invisible Cities*:

'From now on, I'll describe the cities to you,' the Khan had said, 'in your journeys you will see if they exist.'

But the cities visited by Marco Polo were always different from those thought of by the emperor.

'And yet I have constructed in my mind a model city from which all possible cities can be deduced,' Kublai said. 'It contains everything corresponding to the norm. Since the cities that exist diverge in varying degree from the norm, I need only foresee the exceptions to the norm and calculate the most probable combinations.'

'I have also thought of a model city from which I deduce all the others,' Marco answered. 'It is a city made only of exceptions, exclusions, incongruities, contradictions. If such a city is the most improbable, by reducing the number of abnormal elements, we increase the probability that the city really exists. So I have only to subtract exceptions from my model, and in whatever direction I proceed, I will arrive at one of the cities which, always as an exception, exist. But I cannot force my operation beyond a certain limit: I would achieve cities too probable to be real.'

In the Khan's world view, diversity is the result of variations on a theme. The existence of a theme implies the existence of some constraint, and it is this that allows the Khan to make predictions about the possible. Marco Polo would defend a view of selection as an opportunist—a "tinkerer," to use the term of eminent French biologist François Jacob—trying to work with whatever it has at any given time. My own view is that the two positions, although defining different methods of analysis, are complementary. We live in a world of opportunity within constraint.

Pere Alberch is associate professor of biology at Harvard University and associate curator of herpetology at Harvard's Museum of Comparative Zoology. He wishes to dedicate this article to the memory of his friend Toti Arbuzá, who "talked dogs" with him.

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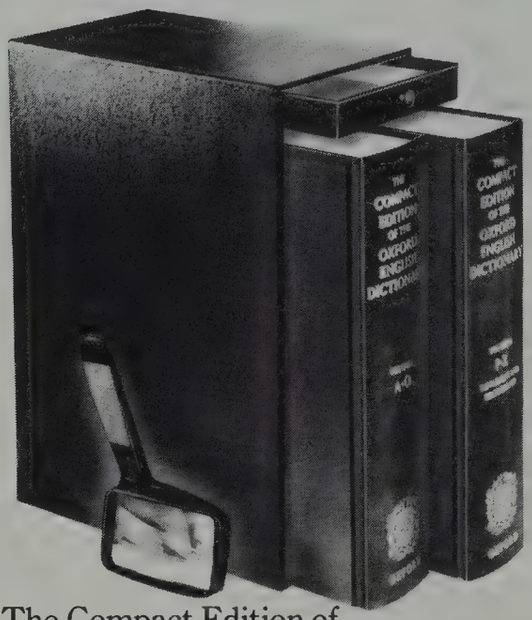

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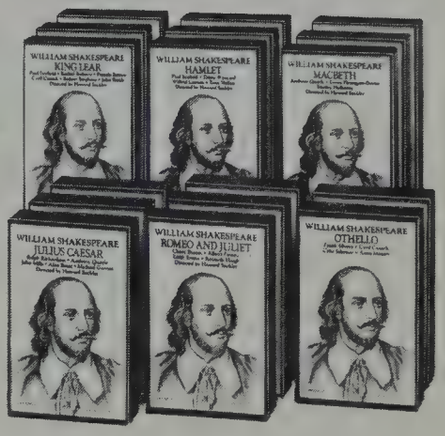

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Glow, Big Glowworm

It behooves parents to respect their offspring, particularly when the youngsters are hungry

by Stephen Jay Gould

Small misunderstandings are often a prod to insight or victory. For such a minor error with major consequences, Laurel and Hardy got into terminal trouble with the toymaster in *March of the Wooden Soldiers*—they got fired for building 100 soldiers six feet high, when Santa had ordered 600 at one foot. But the six-footers later saved toyland from the invasion of Barnaby and his bogeymen.

In insects that undergo a complete metamorphosis, cells that will form adult tissues are already present in the bodies of larvae as isolated patches called imaginal disks. For many years, I regarded this term as one of the oddest in all biology—for I always read "imaginal" as "imaginary" and thought I was being told that this substrate of maturity really didn't exist at all.

When I learned the true origin of this term, I realized that I had not only misunderstood but had made an absolutely backward interpretation. I also discovered that my resolution had taught me something interesting—about ways of looking at the world, not about any facts of nature per se—and I therefore judged my former error as fruitful.

Linnaeus himself, father of taxonomy, named the stages of insect development. He designated the feeding stage that hatched from the egg as a larva (the caterpillar of a moth or maggot of a housefly), and he called the sexually mature adult an imago, hence imaginal disk for precursors of adult tissues within the larva.

The etymologies of these terms provided my insight—a larva is a mask; an imago, the image or essential form of a species. Linnaeus, in other words, viewed the development of insects as progress toward fulfillment. The first stage is only preparatory; it hides the true and complete representation of a species. The final form embodies the essence of louseness, thripsness, or flyness. Imaginal disks, by both etymology and concept, are bits of higher reality lurking within initial imperfection—no sign of "let's pretend" here.

Most impediments to scientific understanding are conceptual locks, not factual lacks. Most difficult to dislodge are those biases that escape our scrutiny because they seem so obviously, even ineluctably, just. We know ourselves best and tend to view other creatures as mirrors of our own constitution and social arrangements. (Aristotle, and nearly two millennia of successors, designated the large bee that leads the swarm as a king.)

Few aspects of human existence are more basic than our life cycle of growth and development. For all the glories of childhood, we in the West have generally viewed our youngsters as undeveloped and imperfect adults—smaller, weaker, and more ignorant. Adulthood is a termination; childhood, an upward path. How natural, then, that we should also interpret the life cycles of other organisms as a linear path from imperfect potential to final realization—from the small, ill-formed creature that first develops from an egg to the large and complex fruition that produces the egg of the next generation.

How obvious, in particular, that insect larvae are imperfect juveniles and imagoes are realized adults. Linnaeus's etymology embodies this traditional interpretation imposed from human life upon the development of insects. When we combine this dubious comparison of human and insect life cycles with our more general preference for viewing developmental sequences as ladders of progress (a prejudice that has hampered our understanding of evolution even more than our resolution of embryology), insect larvae seem doomed to easy dismissal by an aggregation of biases—etymological, conceptual, and parochial.

If we turn to two leading works of popular science, published five years after Darwin's *Origin of Species*—one on life cycles in general, the other on insects—we obtain a good sense of these traditional biases. A. de Quatrefages, great French student of that economic leader among insect larvae, the silkworm, wrote in his *Metamorphosis of Man and the Lower Animals* (1864) that "larvae . . . are always incomplete beings; they are true first sketches, which are rendered more and more perfect at each developmental phase."

An Introduction to Entomology, by William Kirby, rector of Barham, and William Spence, wins first prize among British works of popular science for popularity, for longevity (its first edition appeared in 1815), and for prose in the most preciously purple tradition of "nature writing," as satirized by example in James Joyce's *Ulysses*: "Note the meanderings of some purling rill as it babbles on its way, fanned by the gentlest zephyrs tho' quarrelling with the stony obstacles, to the tumbling waters of Neptune's blue domain . . . ." To which, Stephen Daedalus replies: "Agonizing Christ, wouldn't it give you heartburn on your arse." And for which (among other things) *Ulysses* was once banned from the United States as obscene—although I would sooner exclude that purling rill than a heartburn on any part of the anatomy.

In their first post-Darwinian edition (1863), Kirby and Spence make no bones about their preference for well-formed imagoes and their distaste for grubby lar-

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vae (a redundancy for emphasis of my point—grubs are larvae, and we owe this adjective to the same prejudice):

That active little fly, now an unbidden guest at your table, whose delicate palate selects your choicest viands, one while extending his proboscis to the margin of a drop of wine, and then gaily flying to take a more solid repast from a pear or peach; now gamboling with his comrades in the air, now gracefully currying his furled wings with his taper feet, was but the other day a disgusting grub, without wings, without legs, without eyes, wallowing, well pleased, in the midst of a mass of excrement.

The adult, they write, is called an imago "because, having laid aside its mask [larva], and cast off its swaddling bands [the pupal cocoon, or chrysalis], being no longer disguised [larva] or confined [pupa], or in any other respect imperfect, it is now become a true representative or image of its species."

The burden of metaphor becomes immeasurably heavier for larvae when Kirby and Spence then drag out that oldest of all insect analogies from an age of more pervasive Christianity—the life cycle of a butterfly to the passage of a soul from first life in the imperfect prison of a human body (larval caterpillar), to death and entombment (pupal chrysalis), to the winged freedom of resurrection (imago, or butterfly). This simile dates to the great Dutch biologist Jan Swammerdam, child of Cartesian rationalism but also, at heart, a religious mystic, who first discovered the rudimentary wings of butterflies, enfurled in late stages of larval caterpillars. Swammerdam wrote late in the seventeenth century: "This process is formed in so remarkable a manner in butterflies, that we see therein the resurrection painted before our eyes, and exemplified so as to be examined by our hands." Kirby and Spence then elaborated just a bit:

To see a caterpillar crawling upon the earth sustained by the most ordinary kinds of food, which when . . . its appointed work being finished, passes into an intermediate state of seeming death, when it is wound up in a kind of shroud and encased in a coffin, and is most commonly buried under the earth . . . then, when called by the warmth of the solar beam, they burst from their sepulchres, cast off their cerements . . . come forth as a bride out of her chamber—to survey them, I say, arrayed in their nuptial glory, prepared to enjoy a new and more exalted condition of life, in which all their powers are developed, and they are arrived at the perfection of their nature . . . who that witnesses this interesting scene can help seeing in it a lively representation of man in his threefold state of existence . . . . The butterfly, the representative of the soul, is prepared in the larva for its future state of glory; . . . it will come to its state of repose in the pupa, which is its Hades; and at length, when it assumes the imago, break forth with new powers and beauty to its final glory and the reign of love.

But must we follow this tradition and view larvae as harbingers of better things? Must all life cycles be conceptualized as ladders of progress leading to an adult form? Human adults control the world's media—and the restriction of this power to one stage of our life cycle imposes a myopic view. I would be happy to counter this prejudice (as many have) by emphasizing the creativity and specialness of human childhood, but this essay speaks for insects.

I will admit that our standard prejudice applies, in one sense, to creatures like ourselves. Our bodies do grow and transform in continuity. A human adult is an enlarged version of its own childhood; it retains the same organs, reshaped a bit and often increased a great deal. (Many insects with simple life cycles, or so-called incomplete metamorphoses, also grow in continuity. This essay treats those insects that cycle through the classical stages of complete metamorphosis: egg, larva, pupa, and imago.)

But how can we apply this bias of the ladder to complex life cycles of other creatures? In what sense is the polyp of a cnidarian (the phylum of corals and their allies) more—or less—complete than the medusa that buds from its body? One stage feeds and grows; the other mates and lays eggs. They perform different and equally necessary functions. What else can one say? Insect larvae and imagoes perform the same division—larvae eat and imagoes reproduce. Moreover, larvae do not grow into imagoes by increase and complication of parts. Instead, larval tissues are sloughed off and destroyed during the pupal stage, while the imago largely develops from small aggregations of cells—the imaginal disks of this essay's beginning—that resided, but did not differentiate, within the larva. Degenerating larval tissues are often used as a culture medium for growth of the imago within the pupa. Larva and imago are different and discrete, not before and shadowy versus later and complete.

Even Kirby and Spence sensed this true distinction between objects equally well suited for feeding and reproduction, though they soon buried their insight in cascading metaphors about progress and resurrection:

Were you . . . to compare the internal conformation of the caterpillar with that of the butterfly, you would witness changes even more extraordinary. In the former you would find some thousands of muscles, which in the latter are replaced by others of a form and structure entirely different. Nearly the whole body of the caterpillar is occupied by a capacious stomach. In the butterfly it has become converted into an almost imperceptible thread-like viscus; and the abdomen is now filled by two large packets of eggs.

If we break through the tyranny of our usual bias, to a different view of larvae and imagoes as separate and potentially equal devices for feeding and reproduction, many puzzles are immediately resolved. Each stage adapts in its own way, and depending upon ecology and environment, one might be emphasized, the other degraded to insignificance in our limited eyes. The "degraded" stage might be the imago as well as the larva—more likely, in fact, since feeding and growth can be rushed only so much, but mating, as poets proclaim, can be one enchanted evening. Thus, I used to feel sorry for the mayfly and its legendary one day of existence, but such brevity only haunts the imago, and longer-lived larvae also count in the total cycle of life. And what about the seventeen-year "locust" (actually a cicada)? Larvae don't lie around doing nothing during this dog's age, waiting patiently for their few days of visible glory. They have an active life underground, including long stretches of dormancy to be sure, but also active growth through numerous molts.

Thus, we find our best examples of an alternative and expansive view of life cycles among species that emphasize the size, length, and complexity of larval life at the apparent expense of imaginal domination—where, to borrow Butler's famous line with only minor change in context, a hen really does seem to be the egg's way of manufacturing another egg. I recently encountered a fine case during a visit to New Zealand—made all the more dramatic because human perceptions focus entirely upon the larva and ignore the imago.

After you leave the smoking and steaming, the boiling and puffing, the sulfurous stench of geysers, fumaroles, and mud pots around Rotorua, you arrive at the second best site on the standard tourist itinerary of the North Island—the glowworm grotto of Waitomo Cave. Here, in utter silence, you glide by boat into a spectacular underground planetarium, an amphitheater lit with thousands of green dots—each the illuminated rear end of a fly larva (not a worm at all). (I was dazzled by the effect because I found it so unlike the heavens. Stars are arrayed in the sky at random with respect to the earth's position. Hence, we view them as clumped

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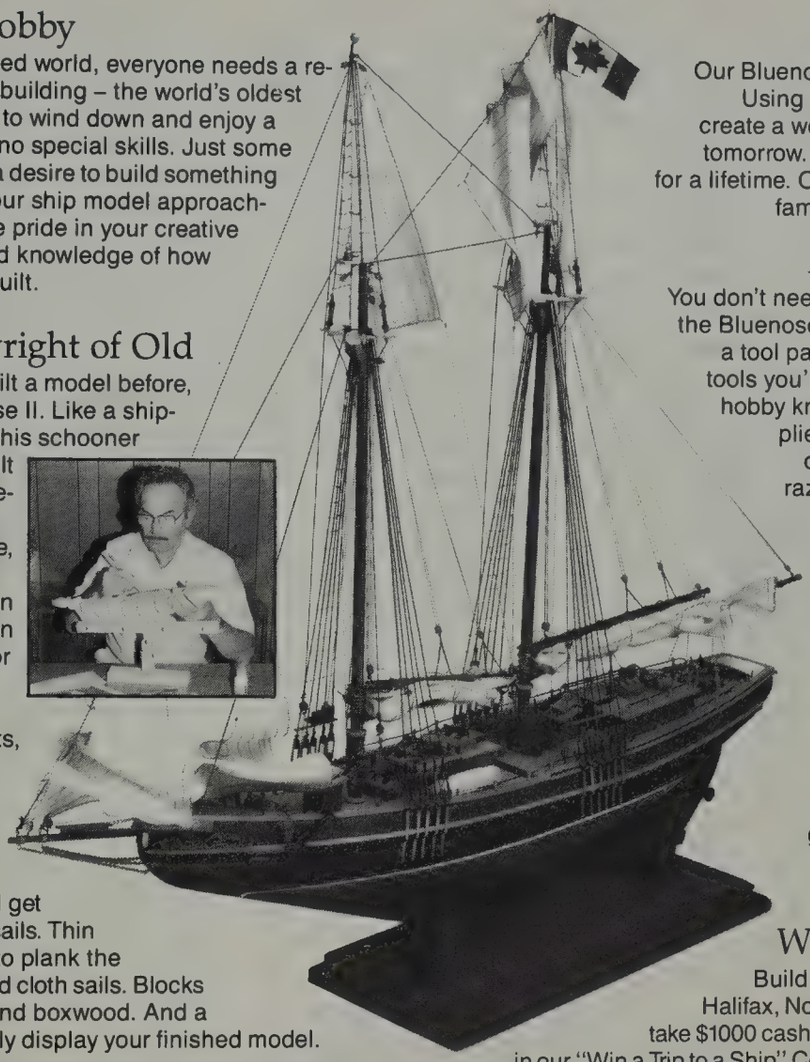

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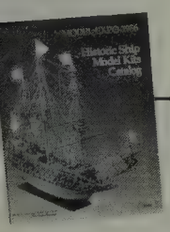

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into constellations. This may sound paradoxical, but my statement reflects a proper and unappreciated aspect of random distributions. Evenly spaced dots are well ordered for cause. Random arrays always include some clumping, just as we will flip several heads in a row quite often so long as we can make enough tosses—and our sky is not wanting for stars. The glowworms, on the other hand, are spaced more evenly because larvae compete with, and even eat, each other—and each constructs an exclusive territory. The glowworm grotto is an ordered heaven.)

These larval glowworms are profoundly modified members of the family Mycetophilidae, or fungus gnats. Imagoes of this species are unremarkable, but the larvae rank among the earth's most curious creatures. Two larval traits (and nothing imaginal) inspired the name for this peculiar species—*Arachnocampa luminosa,* honoring both the light and the silken nest that both houses the glowworm and traps its prey (for Arachne the weaver, namesake of spiders, or arachnids, as well). The imagoes of *Arachnocampa luminosa* are small and short-lived mating machines. The much larger and longer-lived larvae have evolved three complex and coordinated adaptations—carnivory, light, and webbing—that distinguish them from the simpler larval habits of ancestral fungus gnats: burrowing into mushrooms, munching all the way.

In a total life cycle (egg to egg) of ten to eleven months, *Arachnocampa luminosa* spends eight to nine months as a larval glowworm. Larvae molt four times and grow from three- to five-millimeter hatchlings to a final length of some thirty to forty millimeters. (By contrast, imagoes are twelve to sixteen millimeters in length, males slightly smaller than females, and live but one to four days, males usually longer than females.)

Carnivory is the focus of larval existence, the coordinating theme behind a life style so different from the normal course of larval herbivory in fungus gnats. Consider its three principal ingredients:

Luminescence: The light organ of *A. luminosa* forms at the rear end of the larva from enlarged tips of four excretory tubes. These tubes carry a waste product that glows in the presence of luciferase, an enzyme also produced by the larva. This reaction requires a good supply of oxygen, and the four excretory tubes lie embedded in a dense network of respiratory tubules that both supply oxygen to fuel the reaction and then reflect and direct the light downward. This complex and specially evolved system functions to attract insects (mostly small midges) to the nest. Pupae and imagoes retain the ability to luminesce. The light of female pupae and adults attracts males, but the glow of adult males has no known function.

The Nest and Feeding Threads: From glands in its mouth, the glowworm exudes silk and mucus to construct a marvel of organic architecture. The young larva first builds the so-called nest—really more of a hollow tube or runway—some two to three times the length of its body. A network of fine silk threads suspends this nest from the cave's ceiling. The larva drops a curtain of closely spaced feeding threads from its nest. These "fishing lines" may number up to seventy per nest and may extend almost a foot in length (or ten times the span of the larva itself). Each line is studded along its entire length with evenly spaced, sticky droplets that catch intruding insects; the entire structure resembles, in miniature, a delicate curtain of glass beads. Since these lines can be tangled by the slightest current of air, caves, culverts, ditches, and calm spaces amidst vegetation provide the limited habitats for *A. luminosa* in New Zealand.

Carnivory: Using its lighted rear end as a beacon, *A. luminosa* attracts prey to its feeding threads. Two posterior papillae contain sense organs that detect vibrations of ensnared prey. The larva then crawls partway down the proper line, leaving half to two-thirds of its rear in the nest, and hauls up both line and meal at a rate of some two millimeters per second.

The rest of the life cycle pales by comparison with this complexity of larval anatomy and behavior. The pupal stage lasts a bit less than two weeks and already records a marked reduction in size (fifteen to eighteen millimeters for females, twelve to fourteen for males). I have already noted the imago's decrease in body size and duration of life. Imaginal behavior also presents little in the way of diversity or complexity. Adult flies have no mouth and do not feed at all. We commit no great exaggeration by stating that they behave as unipurpose mating and egg-laying machines during their brief existence. Up to three males may congregate at a female pupa, awaiting her emergence. They jockey for position and fight as the female fly begins to break through her encasement. As soon as the tip of her abdomen emerges, males (if present) begin to mate. Thus, females can be fertilized even before they break fully from the pupal case. Females may then live for less than a day (and no more than three), doing little more before they expire than finding an appropriate place for some 100 to 300 eggs, laid one at a time in clumps of 40 to 50. Males may live an additional day (up to four); with luck, they may find another female and do it again for posterity.

As a final and grisly irony, emphasizing larval dominance over the life cycle of *A. luminosa,* a rapacious glowworm will eat anything that touches its feeding threads. The much smaller imagoes often fly into the lines and end up as just another meal for their own children.

To throw in a tidbit for readers interested in the history of evolutionary theory, this tightly coordinated complex of larval adaptations so intrigued Richard Goldschmidt that he once wrote an entire article to argue that light, carnivory, and nest building could not have arisen by gradual piecemeal, since each makes no sense without the others—and that all, therefore, must have appeared at once as a fortuitous consequence of a large mutational change, a "hopeful monster," in his colorful terminology.

This proposal (published in English in *Revue Scientifique,* vol. 86, 1948, pp. 607–12) inspired a stern reaction from orthodox Darwinians. Although I have great sympathy for Goldschmidt's iconoclasm, he was, I think, clearly wrong in this case. As J.F. Jackson pointed out (*American Midland Naturalist,* vol. 92, 1974, pp. 240–45), Goldschmidt made an error in the taxonomic assignment of *A. luminosa* among the Mycetophilidae. He ranked this species in the subfamily Bolitophilinae. All larvae of this group burrow into soft mushrooms, and none show even incipient development of any among the three linked features that mark the unique form and behavior of *A. luminosa.* Hence, Goldschmidt argued for all or nothing.

But *A. luminosa* probably belongs in another subfamily, the Keroplatinae—and, unknown to Goldschmidt, several species within this group do display a series of plausible transitions. *Leptomorphus* catches and eats fungal spores trapped on a sheetlike nest slung below a mushroom. Some species of *Macrocera* and *Keroplatus* also build trap nets for fungal spores but will eat small arthropods that also become ensnared. Species of *Orfelia, Apemon,* and *Platyura* build webs of similar form but not associated with mushrooms—and they live exclusively on a diet of trapped insects. Finally, *Orfelia aeropiscator* (literally, air fisher) both builds a nest and hangs vertical feeding threads but does not possess a light.

These various "intermediates" are, of course, not ancestral to *A. luminosa.* Each represents a well-adapted species in its own right, not a transitional stage to the threefold association of New Zealand glowworms. But this array does show that

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each step in a plausible sequence of structurally intermediate stages can work as a successful organism. This style of argument follows Darwin's famous resolution for a potential evolutionary origin for the extraordinary complexity of the vertebrate eye. Darwin identified a series of structural intermediates, from simple light-sensitive dots to cameralike lens systems—not actual ancestors (for these are lost among nonpreservable eyes in a fossil record of hard parts) but plausible sequences disproving the "common sense" notion that nothing in between is possible in principle.

Please do not draw from this essay the conclusion that larvae are really more important than imagoes, either in *A. luminosa* or in general. I have tried to show that larvae must not be dismissed—as preparatory, undeveloped, or incomplete—by false analogy to a dubious (but socially favored) interpretation of human development. If any "higher reality" exists, it can only be the life cycle itself. Larva and imago are but two stages of a totality—and you really can't have one without the other. Eggs need hens as much as hens need eggs.

I do try to show that child-adult is the wrong metaphor for understanding larva-imago. I have proceeded by discussing a case where larvae attract all our attention—literally as a source of beauty; structurally in greater size, length of life, and complexity of anatomy and behavior; and evolutionarily as focus of a major transformation from a simpler and very different ancestral style—while imagoes have scarcely modified their inherited form and behavior at all. But our proper emphasis on the larva of *A. luminosa* does not mark any superiority.

We need another metaphor to break the common interpretation that degrades larvae to a penumbra of insignificance. (How many of you include maggot in your concept of fly? And how many have ever considered the mayfly's longer larval life?) The facts of nature are what they are, but we can only view them through spectacles of our mind. Our mind works largely by metaphor and comparison, not always (or often) by relentless logic. When we are caught in conceptual traps, the exit is often a change in metaphor—not because the new guideline will be truer to nature (for neither the old nor the new metaphor lies "out there" in the woods), but because we need a shift to more fruitful perspectives, and metaphor is often the best agent of conceptual transition.

If we wish to understand larvae as working items in their own right, we must replace the developmental metaphor of child-adult, with an economic simile that recognizes the basic distinction in function between larvae and imagoes—larvae as machines built for feeding and imagoes as devices for reproduction. Fortunately, an obvious candidate presents itself on the very first page of the founding document itself—Adam Smith's *Wealth of Nations*. We find our superior metaphor in the title of chapter 1, *On the Division of Labor*, and in Smith's opening sentence:

> The greatest improvement in the productive powers of labor, and the greater part of the skill, dexterity, and judgment with which it is anywhere directed, or applied, seem to have been the effects of the division of labor.

By separating the different, sometimes contradictory, functions of feeding and reproduction into different phases of the life cycle, insects with complete metamorphosis have achieved a division of labor that permits a finer adaptive honing of each separate activity.

If you can dredge up old memories of your first college course in economics, you will remember that Adam Smith purposely chose a humble example to illustrate the division of labor—pin making. He identifies eighteen separate actions in drawing the wire, cutting, pointing, manufacture of the head, fastening head to shaft, and mounting the finished products in paper for sale. One man, he argues, could make fewer than twenty pins a day if he performed all these operations himself. But ten men, sharing the work by rigid division of labor, can manufacture about 48,000 pins a day. A human life spent pointing pins or fashioning their heads or pushing them into paper may strike us as the height of tedium, but larvae of *A. luminosa* encounter no obvious psychic stress in a life fully devoted to gastronomy.

All hobbyists and professional entomologists will, no doubt, have recognized an unintended irony in Smith's selection of pin making to illustrate the division of labor. Pins are the primary stock-in-trade of any insect collector. They are used to fasten the dry and chitinous imagoes—but not the fat and juicy larvae—to collecting boards and boxes. Thus, the imagoes of *A. luminosa* may end their natural life caught in a larval web, but if they happen to fall into the clutches of a human collector, they will end up transfixed by the very object that symbolizes their fall from conceptual dominance to proper partnership.

Stephen Jay Gould teaches biology, geology, and the history of science at Harvard University.

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Pennsylvania Pioneers

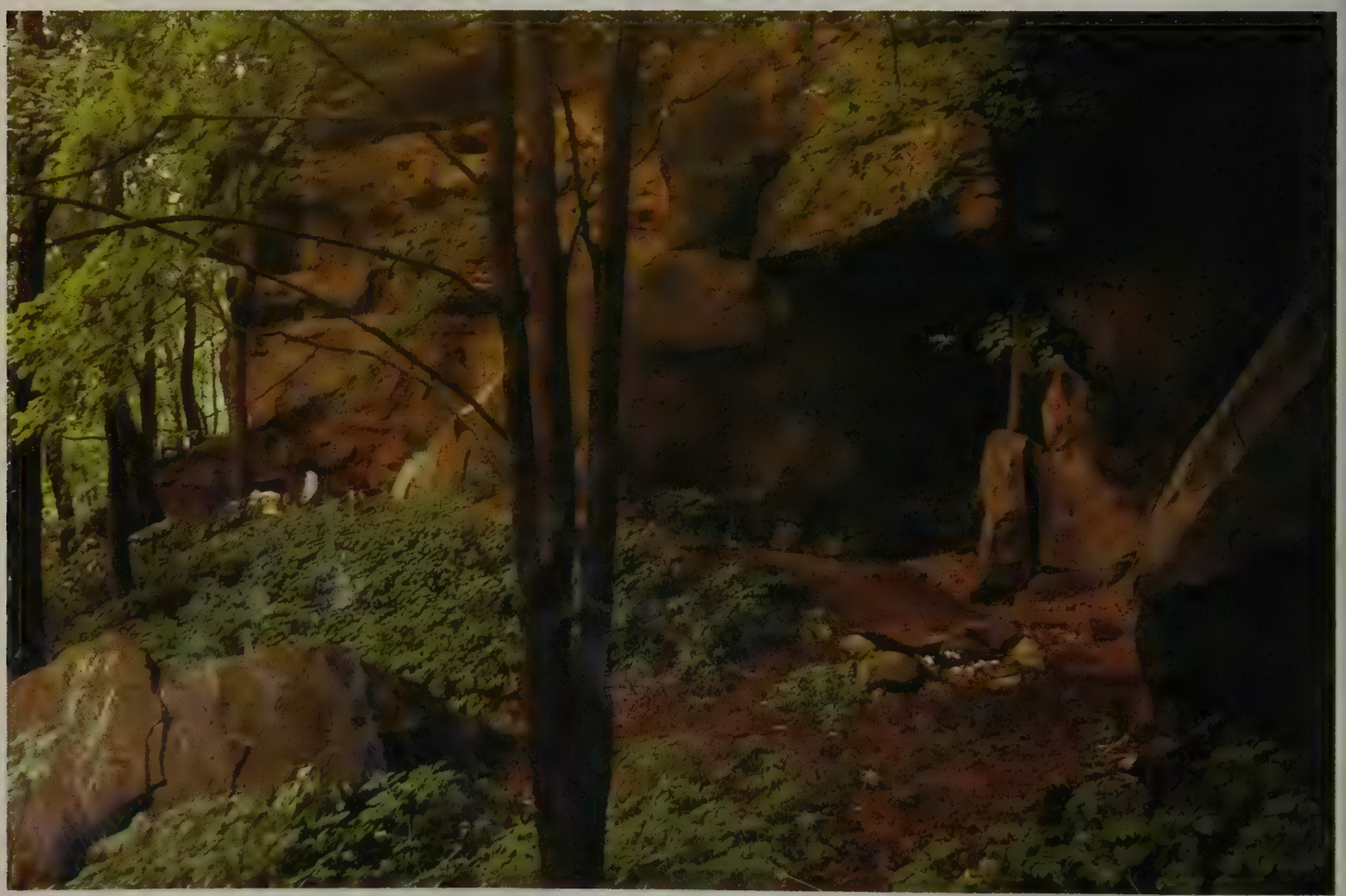
Meadowcroft Rock-shelter adds a long-lost chapter to American history books

by J.M. Adovasio and Ronald C. Carlisle

This is the second in a series of articles exploring archeological sites and other lines of evidence that bear on the peopling of the New World.

In the summer of 1973, archeology students from the University of Pittsburgh dutifully began fieldwork at Cross Creek in southwestern Pennsylvania, excavating beneath a sandstone overhang fifty feet long and up to twenty feet deep—a place where Indians were likely to have camped in prehistoric times. At the time, no one anticipated any great revelations from these efforts because Meadowcroft, as the site is known, had been chosen primarily to offer archeological training at a rock-shelter, a type of setting common in western North America but, because of local geology, rather rare in southwestern Pennsylvania. The project was envisioned as a long-term exercise that would also involve searching for additional sites and studying other aspects of Cross Creek's fifty-five-square-mile drainage area, part of the Ohio River basin. The first season's dig proved unexpectedly promising, however, uncovering, in sediments more than sixteen feet thick, numerous artifacts and sufficient charcoal (in nearly all cases, from fire pits or fire floors) to produce a long series of radiocarbon dates, some so ancient that they provoked controversy.

Results from laboratory tests began to arrive the following winter, and they included one date of about 15,120 years ago. Because this was earlier than the vast majority of previously reported dates for a human presence in the New World, the



Hunter-gatherers sought shelter at Meadowcroft thousands of years earlier than once thought possible. J.M. Adovasio

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first reactions were ones of skepticism, to say the least. As even earlier dates were reported following the next two field seasons, however, the doubts of those working at Meadowcroft evaporated. The oldest directly dated artifact from the site is 19,600 ± 2,400 years old (for a brief description of radiocarbon dating, see the accompanying note, "Safety in Numbers"). This is a two-inch by three-inch piece of carbonized, barklike material, cut along the sides and broken off at the ends. Apparently it is a remnant of a plaited basket or mat; less fragmentary examples of similar manufacture appear at less ancient levels of the site. The age of the basketry fragment places it near the height of the last (late Wisconsinan) glaciation, when glaciers reached within thirty-six miles of Meadowcroft. The presence of an artifact in Pennsylvania at such an early date suggests that human groups must have entered North America at least several thousand years earlier.

Inevitably, this and other early radiocarbon dates from Meadowcroft sparked debate in archeological circles. A major concern was that the carbon samples might have been contaminated with coal particles or soluble organic materials that made them appear older than they were. However, each sample had been thoroughly inspected under special geological microscopes for extraneous particles and extensively treated to remove any organic contaminants. Furthermore, the dates and artifacts from all the higher strata at Meadowcroft seem appropriate, based upon what is known from other sites in the Upper Ohio Valley and the northeastern United States. There is no reason to suppose that the lowest parts of Meadowcroft could have been contaminated without the higher strata also being effected. Finally, subsequent tests, some using a comparatively new carbon-dating technique known as accelerator mass spectrometry, or particle accelerator dating, have reaffirmed the initial dates.

The early dates challenge the current base line of American prehistory, which is defined by certain widely distributed dart points or spearpoints representing what archeologists call the Clovis tradition (named after the site with which they were originally associated, near Clovis, New Mexico). These are chert or chalcedony projectile points used by ancient Indian hunters, apparently mostly in pursuit of big game, including the mammoths that became extinct at the end of the last Ice Age. The points are "fluted," that is, a flake was removed on one or both faces, from the base to about one-third the way to the tip, presumably to make it easy to join the point to the split end of a wooden shaft. (Similar, though smaller, more finely chipped points, with more extensive fluting, are called Folsom points; they were manufactured by somewhat later hunters whose prime big-game animals were Ice Age bison. To date, no fluted points of any type have been found in the Old World.)

Many Clovis points come from surface finds in plowed fields or from other disturbed locations where their age cannot be determined. Specimens at sites that can be dated by radiocarbon techniques generally fall in the range of 11,500 to 11,000 years ago, that is, nearing the approximate end, 10,000 years ago, of the last glacial period. Many conservative archeologists regard these implements as the earliest solid evidence of a human presence in the New World. They suspect, therefore, that humans crossed into North America from Asia after the ice sheets began to recede. Claims of greater antiquity have been raised for a variety of pre-Clovis sites, but the often slender evidence that has been preserved frequently fails to convince archeologists. For the demonstration to be valid, the artifacts must be indisputably of human manufacture (or human remains themselves, should they be found) and must be excavated from undisturbed geological formations that have excellent

A projectile point from New Mexico: the typical "Clovis" pattern, actual size
Eastern New Mexico University; Drawing by Stephen Patricia

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Safety in Numbers: How Reliable Are Radiocarbon Dates?

Radiocarbon dating depends on determining the proportion of carbon 14, a relatively rare, radioactive form of carbon, within a carbon sample. A fairly constant level of carbon 14 is generally maintained in the earth's atmosphere because of continual radioactive bombardment from the sun. Most living plants and animals contain a similar proportion. After an organism dies, however, the proportion changes as the carbon 14 decays into nitrogen. Because the rate of decay is always the same, the proportion of carbon 14 remaining permits scientists to estimate a sample's age.

Contamination of a sample by ancient organic material (such as coal) can throw off the estimation of age. Corrections also have to be made for past fluctuations in the proportion of carbon 14 in the atmosphere (volcanoes, for example, have sometimes added other forms of carbon to the atmosphere, temporarily lowering the proportion of carbon 14; the result is to make the sample appear older than it is).

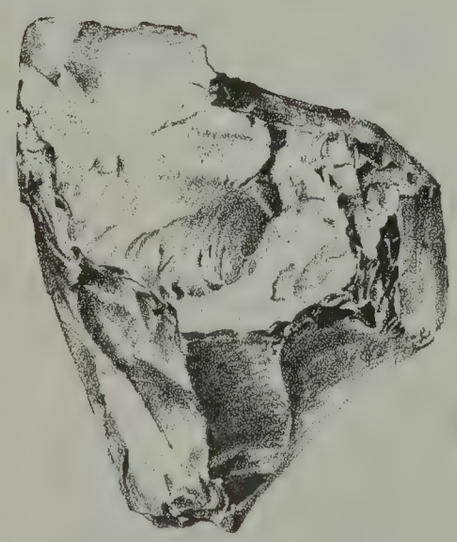
In addition to these complicating factors, there are certain statistical limitations on the accuracy of estimations of age. The radiocarbon method counts radioactive emissions over a standard period of time from the carbon sample to be dated. Because individual emissions are random events, there is room for error in determining their frequency. By convention, therefore, radiocarbon dates are always expressed with a plus/minus range, calculated to reflect the probability for error. The oldest dated artifact from Meadowcroft, a small fragment of basketry, is thus described as being 19,600 ± 2,400 years old. This means that there are two chances in three that the sample in question is between 22,000 and 17,200 years old. If greater certainty is desired, the range must be correspondingly widened. Thus the chances are 95 percent that the sample is between 24,400 and 14,800 years old. For comparison, 12,000 years ago remains, to conservative archeologists, the earliest acceptable conclusive date for a human presence in the New World.

Because of the radiocarbon method's inherent limitations, no single radiocarbon date can really be considered definitive. But the highly consistent series of fifty radiocarbon dates extending from the bottom to the top of Meadowcroft, along with the apparent lack of contamination, is strong evidence that the site is truly ancient.

opportunities for radiometric dating, preferably with multiple dates. In these respects, Meadowcroft has proved a generous site.

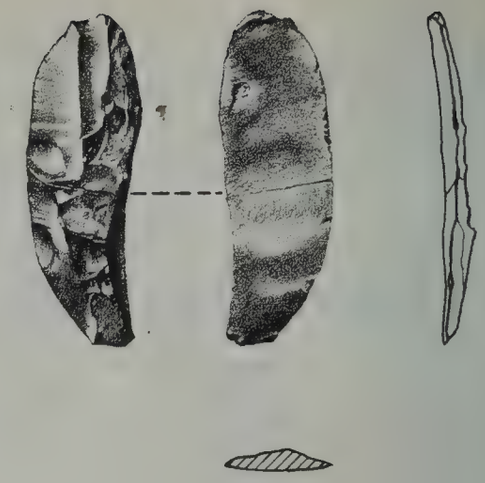
The earliest Meadowcroft deposits, which are about 31,000 to 21,000 years old, contain no artifacts, leading to the conclusion that people had not yet camped at the site. The latest deposits, in contrast, from about 600 to 200 years ago, were formed when traders and a few brave settlers were making the first European advances into the Ohio valley. Between these two extremes, the rock-shelter floor preserved numerous stone tools, pottery, animal bones, thousands of land snail and river mussel shells, nuts, seeds, and other plant and animal remains—the residue of a shadowy, changing prehistoric population that for hundreds of generations had sought protection beneath the south-facing shelter.

All the major cultural periods previously known for Upper Ohio Valley prehistory appear at Meadowcroft, from the hunting-and-gathering Archaic period (about 9,950 to 3,950 years ago) through the various phases of the Woodland period (3,065 to 685 years ago) when horticulture was introduced. The site was probably most frequently visited during the Late Archaic period, when the groups using the site hunted deer, elk, wild turkey, and other game and gathered seeds, nuts, and other plant products. The Woodland deposits have rewarded excavators with many significant discoveries, including the earliest recognized squash and corn in this part of the Ohio River drainage (about 3,065 and 2,300 years ago, respectively), as well as the first indication that



To make long, thin tools with sharp edges, a prehistoric American struck off blades from this stone core, found near Meadowcroft.

Drawings by Stephen Patricia, Department of Anthropology, University of Pittsburgh



Three views and a cross section of a small stone blade from Meadowcroft—such a tool is a rare find for the New World but resembles Ice Age artifacts from Europe and Asia.

Indians of the area were making pottery (also 3,065 years ago).

All these later deposits were examined with equal care, but most attention has been drawn to the more ancient stone tools and fragments of basketry found in the earliest occupied levels of the site. There are two such levels, marked off by major collapses of the rock-shelter roof. The younger of the two ranges in age from about 13,000 to 11,000 years ago, toward the end of Ice Age times. The older one has eight radiocarbon dates ranging from 19,600 ± 2,400 at its base (the basketry fragment) to 12,800 ± 870 years ago.

The early stone artifacts from Meadowcroft—not only the tools but also the discarded flakes created during tool manufacture or resharpening—are the products of a standardized technology. Finished tools, such as unifaces (implements flaked on only one face) and bifaces, are rare in these early levels but include delicately retouched unifacial knives (named Mungai knives, after a particularly helpful local farmer and avocational archeologist), bifacial cutting or slicing tools, gravers (thought to be used in working bone or wood), and an array of small blades. These last are thin, prismatically shaped tools, at least twice as long as they are wide, that were struck off a stone nucleus, or core. A cut, charred base of a deer antler, dated by association with other material to 16,175 ± 975 years ago, is the oldest bone recovered from the site. Although there is no physical indication that this artifact was used as a tool, in Europe, Asia, and elsewhere in the Americas, such objects were used as hammerlike batons to remove small flakes from stone tools.

In 1976, a small, lanceolate (tapered-leaf-shaped) projectile point was found

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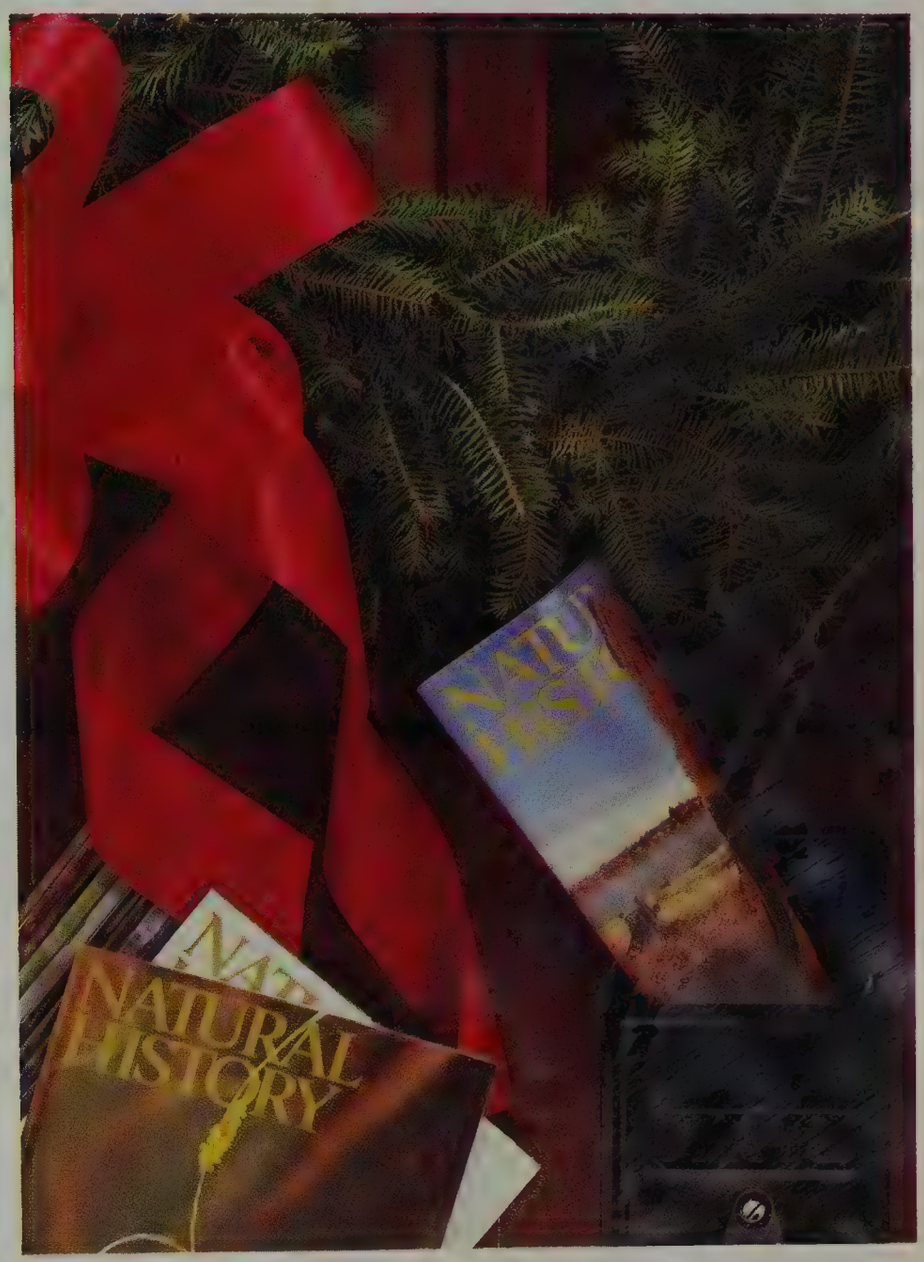

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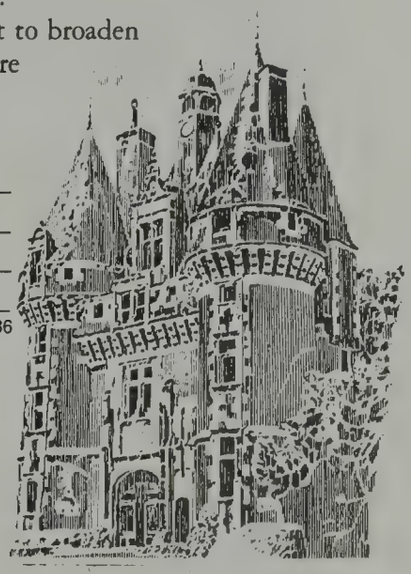

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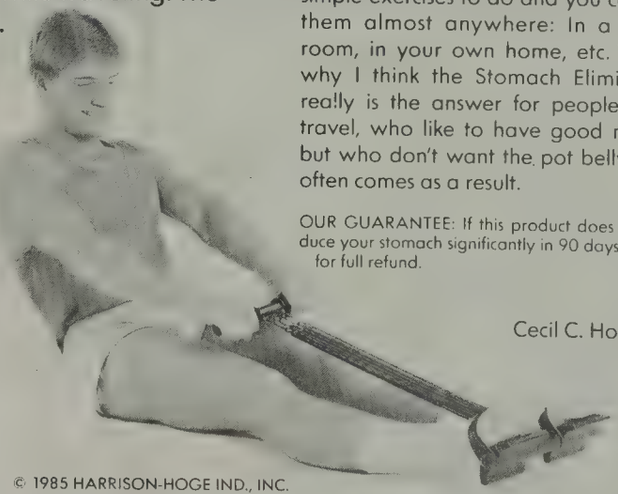

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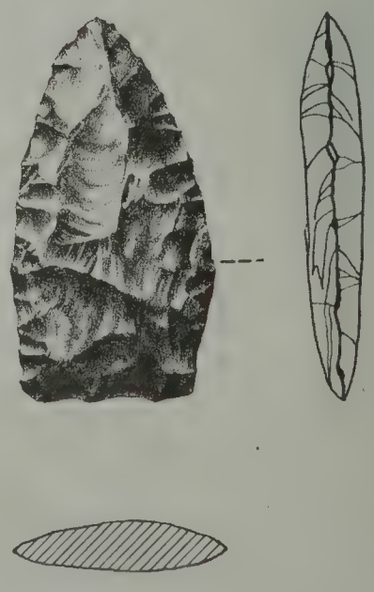
near the top of the earliest level of the site that contains artifacts. Later we called it the Miller lanceolate point, after Albert Miller, the owner of the property where Meadowcroft is located. The Miller lanceolate point is the only projectile point from this early level, but it shows that humans at the time were hunting for game. It and the prismatic blades are of special interest because of their apparent great age and because they reflect an advanced state of knowledge about flaked-stone tool manufacture. The people who made them were as expert at core and blade production techniques as people throughout most of Europe and Asia beginning about 35,000 years ago.

Although individually most of the other early artifacts from Meadowcroft would not look out of place in collections of Clovis tools, the manufacturing of very small blades stands out. The blades were struck off a small core of rock that was first shaped for this purpose. Similar cores, polyhedral in shape because of the way the blades were removed in sequence around the circumference, have been found in Siberia and elsewhere in the Old World. Although none have turned up at Meadowcroft, an (undated) example was found in the Cross Creek drainage, with scars that correspond in size to the Meadowcroft-style blades. The early Meadowcroft stone tools, therefore, possibly represent some kind of link between Old World technology and the more clearly documented early cultures of North America, notably Clovis.

Anthony P. Boldurian, formerly assistant curator of the Blackwater Draw Clovis site, recently tabulated attributes of the early Meadowcroft blades and Miller



The Miller lanceolate point once tipped a hunting spear or a dart.

anceolate point and compared them with ools from four other sites with potential re-Clovis levels. Two of these—Idaho's Wilson Butte Cave and Missouri's Shriver ite—seem to show an early approach to tone tool manufacture that was coarser han techniques used at Meadowcroft, in hat larger flakes were struck from less tandardized cores. However, at the Shoop site in eastern Pennsylvania, some small, Meadowcroft-style blades are present, and once again, these blades do not fit the general pattern for Clovis sites. Shoop was one of the first and is still among the best-known Paleo-Indian sites in the eastern United States, although it is neither stratified nor directly dated by radiocarbon methods. Shoop has yielded many artifacts to professional and avocational archeologists since 1936, most of which appear to be part of the eastern Clovis stone tool technology, with some larger blades also very similar in shape to specimens from the Plains.

Finally, eleven stone flakes and two projectile points recovered from the lowest level at Fort Rock Cave, Oregon, bear a marked similarity to early artifacts from Meadowcroft. In particular, there is a lanceolate point with a thinned base that is similar to the Meadowcroft Miller lanceolate point, and the earliest small blade from Fort Rock is indistinguishable from the Meadowcroft prismatic blades or others from the Cross Creek drainage. Fort Rock Cave has a single radiocarbon date of 13,200 ± 750 years ago from its lowest level. Unfortunately this level may have been disturbed by wash from an adjacent Ice Age lake, either about the time the artifacts were originally deposited or sometime afterward. Thus the validity of the association between the artifacts, the site level, and the radiocarbon date is currently being debated.

Archeologists may someday conclude that the small stone blades, cores, and flakes from Meadowcroft and these other sites belong to a single, widely distributed pre-Clovis technology and culture. Some or all of these groups of artifacts, however, may simply prove to be specialized parts of a larger flaked-stone tool industry that also included, or came to include, the distinctive Clovis fluted point. The extent to which the people who produced them predated those responsible for the Clovis big-game hunting points will be determined when additional well-dated sites can be joined to the evidence from Meadowcroft. Only then will archeologists have demonstrated, once and for all, that human groups crossed the land bridge from Asia to North America well before the end of the last Ice Age. □

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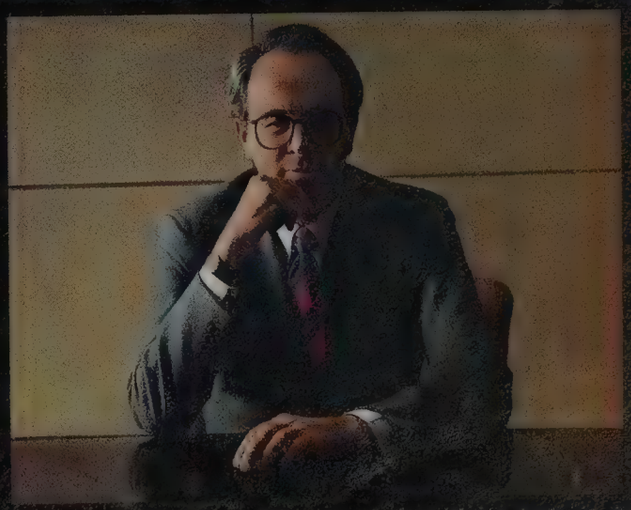

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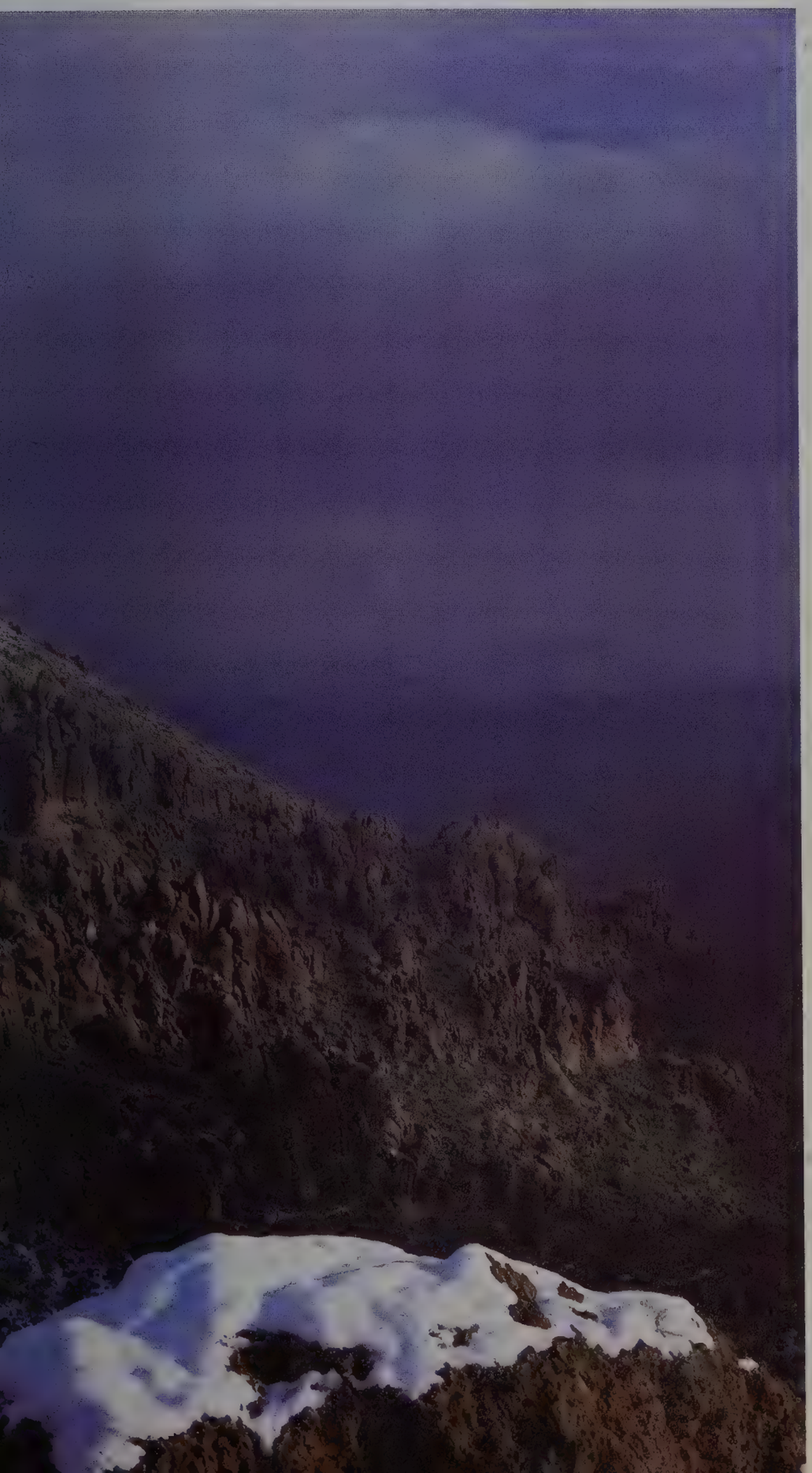
From its broad base to its slender tip, Weavers Needle, a weathered hunk of ancient lava, measures 953 feet.

Tom Danielsen

Peralta Canyon, Arizona

by Robert H. Mohlenbrock



East of Phoenix, Arizona, in Tonto National Forest, the arid Superstition Mountains rise above the northeastern edge of the Sonoran Desert. One of the landmarks of this volcanic range is Weavers Needle, a pinnaclelike remnant of eroded lava. The rumor that the Lost Dutchman Gold Mine lies hidden somewhere up in the hills makes the region even more intriguing. One recent autumn, with visions of being the one to rediscover the gold, I hiked to Weavers Needle along a well-traveled route up Peralta Canyon.

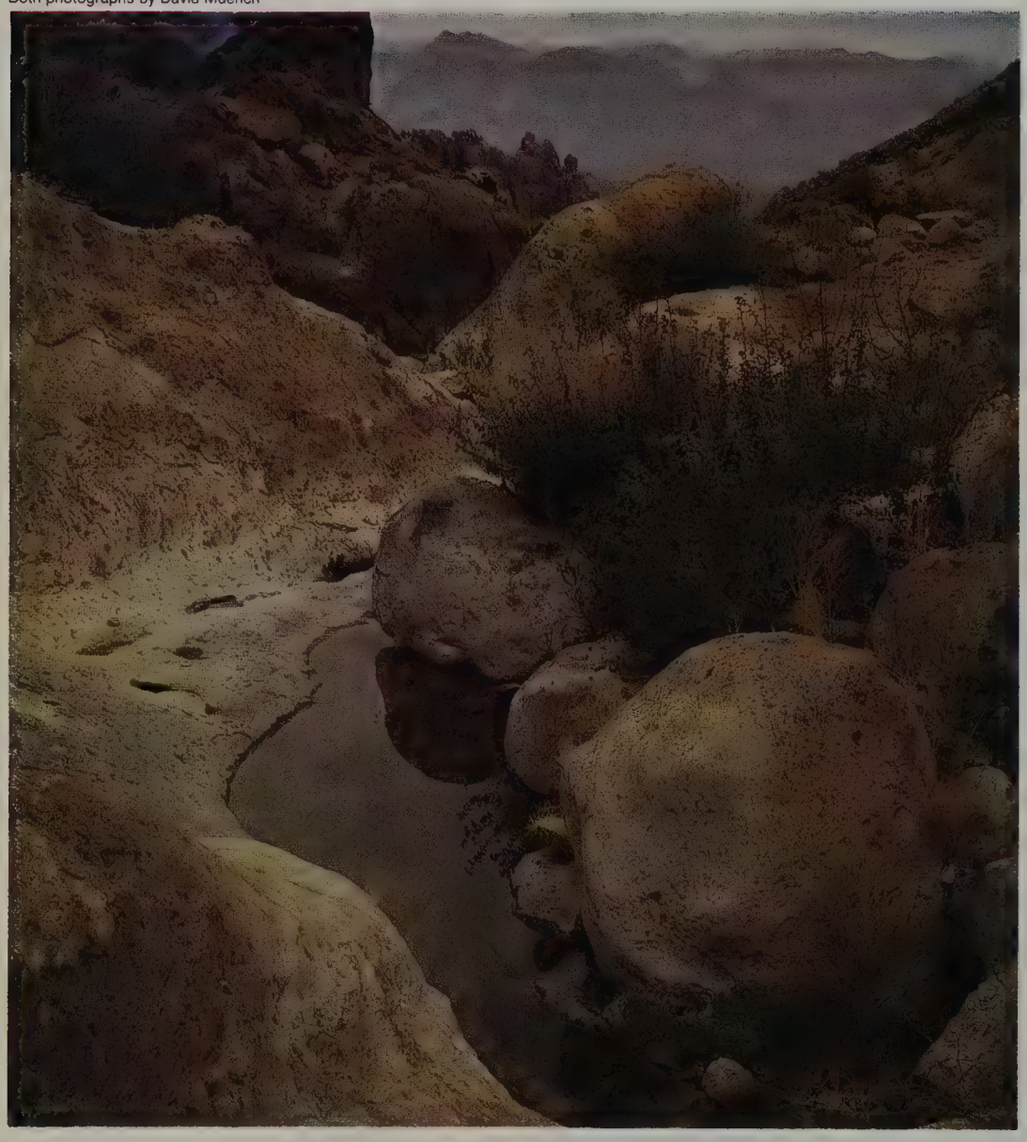
The trailhead is located in the desert, some twenty-five miles east of Phoenix. It starts at 2,400 feet, in a basin at the foot of the Superstition Mountains. Jagged cliffs of a glassy quartz called dacite frame the area. A prominent feature of the landscape is the saguaro, the giant, sometimes comical-looking columnar cactus that may grow to thirty-five feet, although its spreading root system rarely penetrates deeper than three feet.

For the first mile and a half, the trail climbs 1,200 feet, rising through different vegetation zones. At first, small round-topped foothills paloverde trees, with tiny yellow-green leaflets, are scattered across the desert floor. Teddy bear cholla, a yellow-spined cactus that looks misleadingly soft, is also common. But as the trail climbs up the creek bed of Peralta Canyon, a diversity of short trees and shrubs appears, including desert hackberries, ironwoods, velvet mesquites, Emory oaks, and cat's claw acacias. Although the Sonoran Desert has a lot of bare spaces and appears to be very open, most of the trees and shrubs are surrounded at their base by small perennials that are able to live in the shade. The saguaros, on the other hand, usually stand alone, since they cast little shade.

The trail occasionally crisscrosses the canyon's rocky stream bed. Where pockets of moisture accumulate, small ferns, mosses, liverworts, and clubmosses sometimes grow beneath deep-green-leaved sugar sumac trees. Finally, after a series of switchbacks, the trail reaches a 3,800-foot summit known as Fremont Saddle. At this elevation, several grasses dominate the vegetation. Short-statured Arizona rose-

Pockets of vegetation dot arid Peralta Canyon, accessible by trail from the desert floor, below. Brittlebush, a slow-growing shrub found on the desert floor, blooms in front of the Superstition Mountains, opposite.

Both photographs by David Muench



wood and jojoba trees are the prevailing woody plants, beneath which grow agaves, hedgehog cactuses, and beargrass. The Superstition Mountains are visible in their full splendor from this vantage point; Weavers Needle looms mightily about one mile ahead.

The Sonoran Desert is one of four deserts occupying parts of western North America. Forrest Shreve, who in the first half of this century spent his botanical career studying North American deserts, defined their characteristics. They are regions of low and unevenly distributed rainfall, low humidity, high air temperatures with great daily and seasonal ranges, and very high surface soil temperatures. Desert streams flow only sporadically, and the soil, low in organic content and high in mineral salt content, is subject to violent erosion by water and wind.

Most northern of the western deserts is the Great Basin Desert, centered in northern Arizona, northern New Mexico, and Utah but with tongues that extend as far as Washington and Oregon. This desert lies mostly above 4,000 feet, occupying the valley floors between numerous mountain ranges. Precipitation is between four and eleven inches annually, usually in the winter, frequently in the form of snow. The Chihuahuan Desert, mainly in central Mexico but penetrating into southern New Mexico and extreme southeastern Arizona, is somewhat warmer because of its slightly lower elevation and more southerly position. There, rain falls mostly between mid-June and mid-September. In southern Nevada and adjacent California, the smaller Mojave Desert receives only two to five inches of rain, nearly all in late winter. It occupies terrain from sea level to 1,400 feet. Plant life in the Great Basin,

Peralta Canyon

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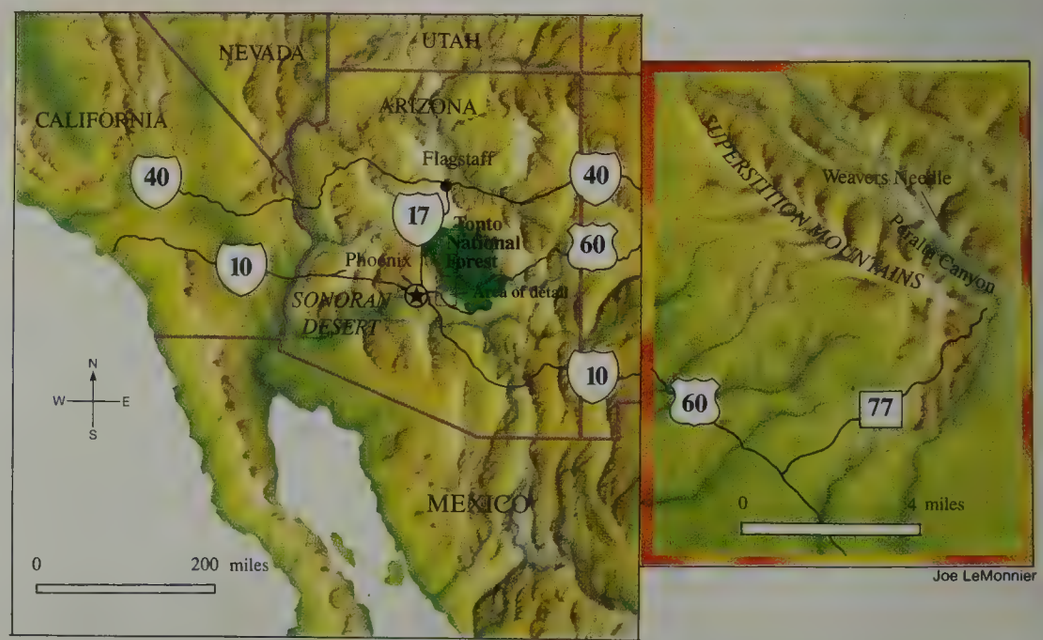

Joe LeMonnier

The saguaro cactus is the hallmark of the Sonoran Desert, a 120,000-square-mile area that ranges from Arizona and southern California into Mexico.
Willard Clay

Chihuahuan, and Mojave deserts appears similar because of the many low shrubs.

The 120,000-square-mile Sonoran Desert covers much of central and western Arizona, southern California, and Baja California, with a strip on the east side of the Gulf of California. Although no single plant community ranges unchanged over such a large area, the Sonoran Desert looks different from the other deserts because of its tree-sized cactuses and succulents. There are two periods of rain each year, from December to mid-April and again from July to early September, with intervening periods of drought. Total annual rainfall averages from three inches in the driest parts to more than twenty inches. The aridity of the Sonoran Desert is maintained by high-pressure cells that prevail between 23° and 30° north latitude. In addition, mountains west of the Sonoran Desert intercept much of the moisture in the air coming from the Pacific Ocean.

Until a decade ago, most scientists believed that the North American deserts had been around for many millions of years, but botanist Daniel Axelrod of the University of California at Davis, after studying the fossil floras in these regions, has concluded that in their present form, the deserts have existed for only about 10,000 years. Citing geological changes that have been brought about in part by movement along the San Andreas Fault and the opening of the Sea of Cortez, Axelrod has shown that the topography of the Sonoran Desert today is far different from what it was during most of the past 80 million years. Fossil evidence indicates that the vegetation went from savanna to dry tropical forest to short-tree forest to woodland chaparral to thorn forest before becoming the desert that it is today. These changes in plant life resulted from a progressive drying out of the area and a strengthening of the high-pressure system, which increased periods of drought.

The ancestors of many of the plants that live in the Sonoran Desert originally grew in cooler and moister climates. Their descendants apparently persisted by adapting to increasingly drier conditions. The succulents store large amounts of water; other plants have compact leaves or no leaves at all, thus reducing water loss. Some plants have extensive root systems that spread laterally beneath the plant. And some short-lived herbs sprout within days, following heavy rains in summer or winter. Their rapid growth, followed by early flowering and seed maturation, completes the life cycle within six to eight weeks, before the next drought begins. These ephemerals often spring up overnight in great masses, prompting aficionados to rush to the desert to see it in bloom. To look for these flowers at any other time is like hoping to stumble across the Lost Dutchman Gold Mine!

ERRATUM: In "Tajique Canyon, New Mexico" (October 1986), Mount Taylor was described as the state's tallest mountain. New Mexico has several higher summits; the tallest is Wheeler Peak.

"This Land" highlights the biological phenomena of the 153 U.S. national forests. Robert H. Mohlenbrock is distinguished professor of botany at Southern Illinois University at Carbondale.

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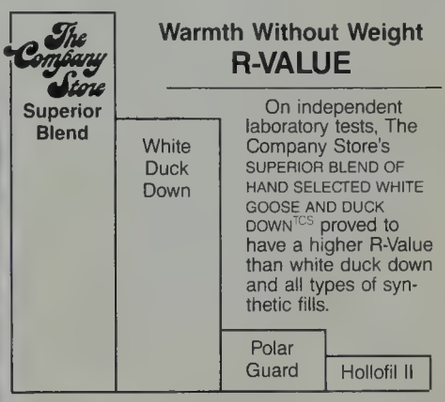
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Our Gang, Ostrich Style

The big bird practices communal child care and even kills lions in defense of newly hatched chicks

by Lewis M. Hurxthal

My ostrich research in Kenya began some sixteen years ago, very much as a family affair. I had made a trip into the bush outside Nairobi and with official permission had gathered six ostrich eggs, intending to hatch and raise the young in captivity. Nancy, my wife and co-worker, who was recovering from surgery, agreed to "brood" the grapefruit-sized eggs in her bed while I constructed an incubator.

Three weeks later, six healthy young hatched in the incubator. The precocial chicks, each about the size of a barnyard hen, proceeded to imprint on Nancy, the first living being they saw after hatching. They followed her everywhere, emitting tremulous, mournful cries when left alone. This scenario seemed appropriate, since my research interest lay in ostrich breeding strategies.

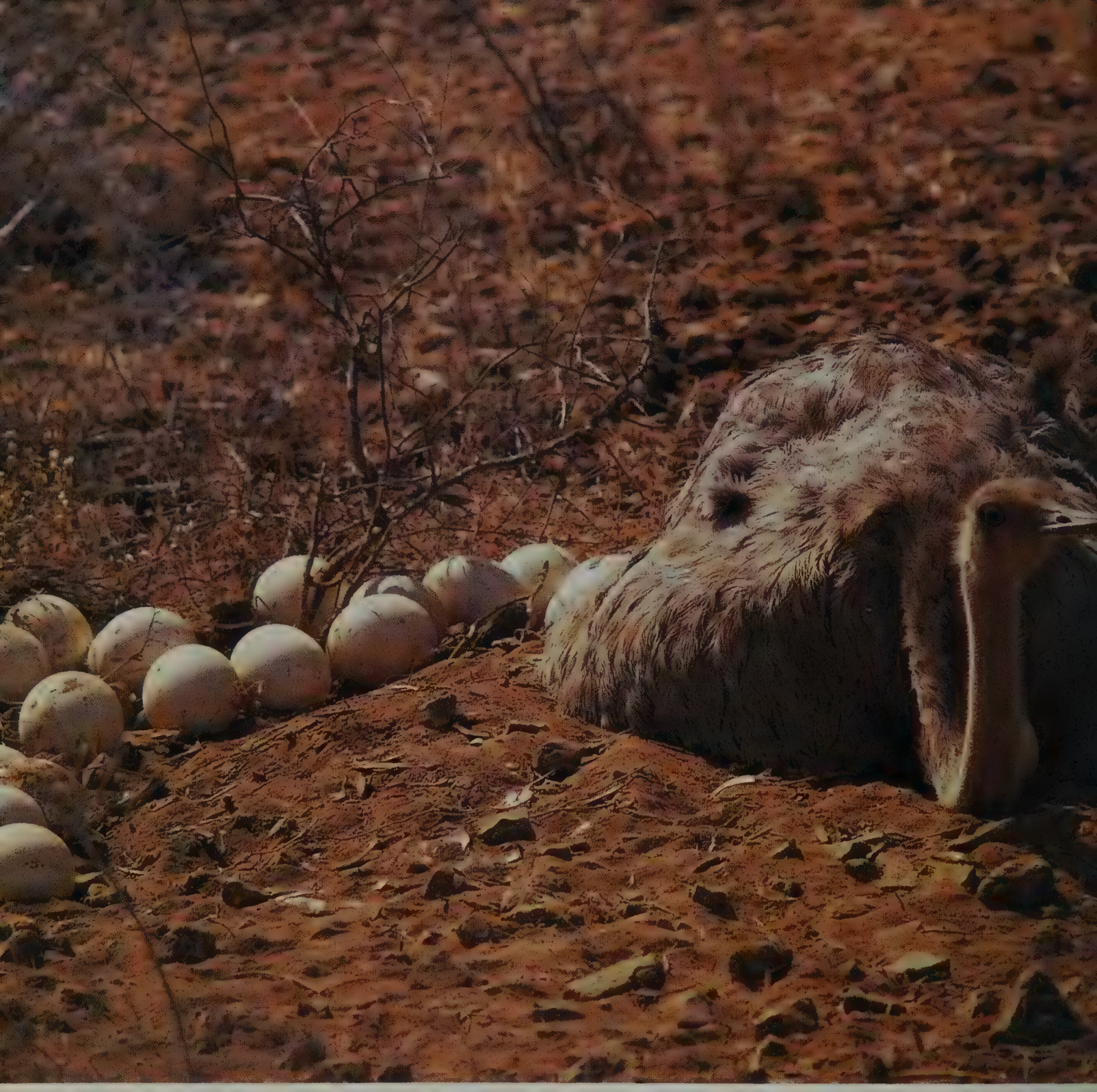
Nancy and I soon learned that we were far from the first humans to raise ostriches or even to incubate the eggs ourselves. These birds, the largest on earth, have had long and intimate associations with humans. Prehistoric rock artists of the Sahara frequently depicted ostriches, and the ancient Egyptians and many other African peoples raised the huge birds in captivity, as did the Romans. In the late nineteenth century, ostriches were domesticated, and some ostrich farms are still in operation today, although tourism and the sale of skins have largely replaced the flourishing plume trade.

Ostriches and their relatives, most of which are also large and flightless, are ratites. The ostrich's closest relative is the South American rhea, which weighs only a third of the ostrich's 220 pounds but prefers similar habitats and exhibits some of the same behavior. Well adapted to the semiarid conditions of savannas, as well as to areas of higher rainfall where vegetation is often thick and lush during the rainy season, ostriches live throughout Africa, although their range is dwindling.

In spite of its long association with humans, the detailed behavior and ecology of the ostrich in the wild were virtually unknown in terms of modern zoology when I began my study at the University of Nairobi. I was especially concerned with the breeding behavior of the Masai

A male displays just before mating

John H. Hoffman; Bruce Coleman, Inc.



ostrich, a subspecies found only in Kenya and Tanzania. In Nairobi National Park I found an ideal situation for my observations. Here many ostriches lived in their natural habitat, yet had grown accustomed to motor vehicles, so that I could approach them closely.

Only after several seasons of fieldwork could I outline the behavior, particularly breeding behavior, of the ostrich during a typical year in Nairobi Park. In May or June, adult males begin to display their breeding color, a pink flush on the skin of the neck and legs. About half of these males establish a territory of roughly one square mile, which they aggressively defend against other mature males. Adult females, more numerous than the males, do not defend territories, but each remains on a much larger breeding home range of about five square miles, which embraces five to seven male territories.

During July, individual hens begin to seek out and mate with territorial males. Soon they begin to lay eggs at nest sites already chosen and prepared by the males. Only about one in three hens finds a permanent mate; such females are called major hens, and their pair bond with a particular cock may last for many years. The remaining, minor hens form no pair bond. They mate with many different territorial males during a season but must lay their eggs in the nests of established pairs. (Minor hens and nonbreeding males may form temporary groups, which are unstable, with individuals joining or leaving at will.) Each male's nest receives eggs from about ten minor hens. Thus, the resultant communal clutches are large, containing forty eggs on average. Only major hens incubate eggs, their own and those of the minor hens. The cock incubates more often than the hen, sitting at night and for part of the day. After the chicks hatch, the pair escort them away from the nest, leading them to edible plants and protecting them from predators.

Egg hatching takes place during October and November and coincides with Kenya's short rainy period, when a flush of tender young plants emerges. After the synchronized hatch, escorted broods of chicks from different nests eventually

Laura Riley; Bruce Coleman, Inc.

Her dusky plumage serving as camouflage, a hen, left, covers a communal nest in which she and many other females have laid eggs. A hen can incubate an average of twenty-one eggs; excess eggs are discarded, like those at the side of the nest, and will perish. Unlike many other predators, Egyptian vultures have hit upon a way to break open thick-shelled ostrich eggs. The bird in juvenal plumage, below, will learn to not simply drop, but heave, stones at the eggs.

Lewis M. Hurxthal

meet. The dominant parents aggressively round up other chicks to join their own, and by February all the young form one great nursery, or crèche, of thirty to one hundred chicks, escorted by only two or three of the original parents. Chicks grow rapidly and by July are left on their own, much reduced in number by predation by lions, jackals, and other carnivores. Their parents then start the breeding cycle for the next year.

This breeding pattern proved similar to that of other ostrich populations in East Africa. Nairobi Park's ostriches, however, numbered about 170 individuals in a forty-four-square-mile area. This is a high density, and the many hens produce unusually large clutches.

Long before I had enough information to outline the ostrich breeding system, Mike Norton-Griffiths, a fellow ornithologist, challenged me to explain how such a breeding system could evolve or be adaptive. He argued that one hen obviously did not lay forty eggs, yet only one hen cared for them. Why should she sit on the ground in broad daylight, week after week, with lions about, incubating another ostrich's eggs? Mike called this "the paradox of apparent altruism." But this was only half the problem, since an ostrich cock also risks his life on another's eggs, sitting at one spot every night for six weeks of incubation. Early in the study, I found yet another example of apparent altruism. I sighted a flock of 107 two-month-old chicks, carefully led and guarded by one cock and one hen. I soon realized that these chicks must have come from more than a dozen nests, spread out over many miles of savanna, each with its own cock and hen. The single pair escorting the 107 chicks could not have been the parents of all. Yet these escorts commonly defended large broods and even attacked threatening predators.

Thus, parent ostriches expend time and energy, and risk being preyed upon themselves, to protect and care for many eggs and chicks, only a few of which are their own. Similar examples of apparent altruism are found in many animal species. In almost all cases studied in detail, however, the individuals receiving the benefits of an altruistic act are kin, that is, they are genetically related to the "altruistic" individual. This phenomenon, known as kin selection, makes sense in evolutionary terms, because the self-sacrificing individual insures the survival of the genes it shares with close relatives.

An ostrich's apparent altruism cannot easily be explained by kin selection. Because their communal nests contain the eggs of many hens, and because of their somewhat indiscriminate mating system, ostriches can never be sure which egg is related to which hen. We are left with a challenge to current evolutionary theory: What survival value does this behavior hold for the individual ostriches involved? How did such behavior evolve?

The explanation was likely to be found only through a detailed investigation of the breeding system. The apparent altruism seemed to be related to communal breeding or to environmental factors or perhaps to one of the other unusual characteristics of the ostrich, such as its extraordinarily large size.

Aspects of communal breeding were easily observed. One afternoon soon after

Lewis M. Hurxthal

Lions prey on ostrich chicks and eggs. Below, an ostrich caught off guard paces in the distance, as a watchful team of lions surrounds the remnants of a nest. Adult ostriches tending newly hatched chicks have been known to kill young lions. At right, a cock, fiercely pursuing another, lashes out with a kick. Brief fights between males are common and help establish a pecking order.

Carol Hughes

I had begun my study, Nancy spotted a hen behaving in a peculiar way. Driving to a better vantage point, we discovered our first nest and on it a laying hen. As we watched, another hen appeared, and within twenty minutes, two others slowly walked up to the nest. The three were awaiting their turn to deposit eggs. We knew that the hens laying the next day would be different individuals, because an ostrich needs two days to form each egg. Eventually we found that thirteen hens had laid, placing a total of forty-two eggs in that one nest. This was about average for Nairobi Park. We were at a loss to explain why so many hens laid in each nest, and why, when a hen can cover only about twenty-one eggs, so many extra eggs, which could not be incubated, were placed there. Then an unexpected event made clear the hazards of the environment in which ostriches raise their young.

Tony Archer, a knowledgeable naturalist who arrived on the scene just after the occurrence, reported that an ostrich had killed two lions. A Masai man had witnessed the whole dramatic episode, and Tony had questioned him carefully. There in front of them were two dead lions, three-quarters grown, and a dead adult ostrich hen. The Masai said he was watching an ostrich pair with their newly hatched chicks feeding peacefully. Suddenly a lioness appeared with three of her own young. The cock immediately led the chicks to safety while the hen advanced on the predators. A hen with newly hatched chicks is often savage. The young lions began to close in and within a minute or two there was a brief but violent struggle. When the animals parted, two young lions had fallen, one with a broken back and the other with a blow to the head caused by the hen's rapid, powerful downward kicks. Seconds later the lioness pounced on the hen and killed it with a few bites.

Ostriches naturally use their large size and powerful legs to defend their young. They are the only flightless birds of Africa, living in one of the most dangerous habitats on earth. The list of their larger predators is formidable. Jackals, hunting dogs, cheetahs, leopards, lions, and of course, humans all regularly prey on ostrich adults, young, or eggs. Smaller mammals such as servals also pose a threat. In addition, about ten species of birds of prey can kill a newly hatched ostrich chick, and one, the Egyptian vulture, can break open the thick eggshell. The other large ratites—the rhea, cassowary, and emu—have only two or three major predators. Furthermore, the ostrich is the only ratite in which both parents escort and protect the young; for the others, the male alone is apparently enough of a defense.

The ostrich's reproductive potential, relatively high for a large animal, may be related to heavy predation. If no young died, the population could increase by five times in one year. But this could only happen in a predator-free environment. During one year of my study, 152 chicks left fifteen nests in Nairobi Park. A year later only 16 young had survived. Ninety percent had died, most killed by predators, and a similar rate of predation is common every year.

Predation has yet another influence on ostrich breeding: it does not affect both sexes equally. Another case dramatized this point. Judith Rudnai, a good friend of mine studying lion behavior in Nairobi Park, kept me informed of lion predation on ostriches. One day she announced that one of "her" lions had killed one of "my" ostriches at a nest. I went to the spot she described and found eggs scattered all about, although only a few were broken. The ostrich had been devoured, except for bones and feathers. Everywhere black-and-white feathers contrasted starkly with the brown-and-green landscape.

Conspicuous plumage may have been the reason the cock had been discovered and killed by lions. Gaudy feathers may be of value in courtship, but they are a liability for a bird sitting on a ground nest for six weeks. The following year I saw another cock dead at his nest, also killed by lions. More males than hens are killed, perhaps because the females' brown-and-gray plumage blends in much better with the landscape.

The result of such unequal mortality is a biased sex ratio, with many more hens than cocks remaining in the population. But there are also other reasons for this bias. Hens mature more quickly, so the start of a breeding season for any age group finds more females than males ready to mate. Also, cocks must hold territories before hens will mate with them. To establish a territory, a young cock may have to pit his strength against older, experienced cocks. A younger male is usually chased away and even kicked for his

trouble. He may have to try for years before he is successful. Thus, the need to hold territories further deters males from breeding.

As soon as a sexually mature, territorial male starts to prepare a nest, predators make an appearance. Egyptian vultures, jackals, hyenas, and lions discover and destroy many nests before the clutch is complete. If a nest is annihilated, the hens may then lay in another nest, while the cocks may not be able to start another nest until the next year. So ostrich populations, like those of most animals, begin with equal numbers of males and females at birth, but by the time the young are ready to breed, there may be only one cock for every three or four laying hens.

In addition to sex ratio, the weight of the ostrich is significant. Large size is obviously an advantage against predators, but size also has a special meaning concerning eggs. Many small birds lay eggs that weigh about 10 percent of the weight of the adult. The ostrich lays an egg only about 1.5 percent of its body weight. Large birds in general lay much smaller eggs in relation to their body size than do small birds. Large eggs have disproportionately great volume. Their formation and growth time is prohibitively long. Most large birds have evolved relatively small eggs in response to this constraint. Thus, although it weighs as much as two dozen chicken eggs, the ostrich egg is smaller than that of most other birds relative to body weight. Even the combined weight of all the eggs of one female ostrich is small taking into consideration her body weight.

The relatively small egg provides a key to understanding communal laying. A major hen usually lays only about seven eggs but can cover about twenty-one. This means that when she finishes laying all her eggs and is ready to incubate, there is room for more. The minor hens, without a nest or permanent mate, put their eggs beside those of an established pair; some of these will be incubated. The small egg and the biased sex ratio are two factors that help us understand communal breeding and how so many hens manage to lay in one nest.

In September of one field season, I watched the cock I had named Interloper scrape the ground with his great claws and show the spot to Pointyhead, his major hen of many years. A week later, eight eggs were laid on the site during one afternoon, although only one was Pointyhead's. During the next afternoon, nine different hens laid nine more eggs. I found that Pointyhead and sixteen other hens were laying in that one nest, and by the time they had finished, two weeks later, the communal clutch had grown to sixty-eight eggs, considerably larger than the average forty-egg clutch.

Typically, a major hen like Pointyhead initiates laying. She deposits one egg every two days for about two weeks, thus laying a total of about seven eggs. Within several days of her first egg, a few minor hens find the nest and also start laying. Other minor hens, not finding the nest until quite late, perhaps contribute only one or two eggs. In Nairobi Park, an average of ten hens lay eggs in each nest. When ready, the major hen rearranges the clutch. She places about twenty-one eggs in the center and moves all the rest about a yard away from the nest. She and the cock then start incubating the central eggs. The other eggs will perish. This behavior raises the question of how the major hen can recognize her own eggs. If she cannot identify them, the many eggs of the minor hens could confuse her and prevent her from incubating and hatching her own.

Kenneth Garrett

In parts of Kenya, chicks from nests in a twenty-mile area form a single crèche, escorted by just two or three of the original parents. Dominant escorts will allow a merger only after they have scutinized and approved of the other brood. In a possible merge in progress, below, a cock is aggressively approached by another male with wings outstretched. On a few remaining ostrich farms in South Africa, the birds are raised and managed as flocks, right. At the turn of the century, ostrich feathers were in great demand. Today, showy feathers are periodically cut, but much of the farms' revenue comes from ostrich skins and tourism.

Lewis M. Hurxthal

Zoologist Bryan Bertram became interested in what he called "the behavior of ostrich eggs." After my study, he went on to investigate this phenomenon. In Tsavo West Park, in Kenya, he tried to find exactly which eggs the major hen moved out of her nest and which she kept in. This proved difficult to determine, but by marking eggs and identifying hens at many nests, he concluded that a major hen can distinguish her own eggs from the many others in a nest. She can thus keep them in the center of the nest to be incubated when she displaces the others. But since the minor hens have a chance to get some of their own eggs incubated, they also benefit. And the cock may benefit even more. If he fertilizes some minor hens, as well as his major hen, many more of the chicks that hatch will be ones he has fertilized.

Even though the cock and hen share the incubation task, he sitting at night and she during the day, the six weeks of incubation is a difficult time. Young, inexperienced pairs, in particular, seem to find sitting for six weeks a tedious job. Sometimes the cock or the hen is late coming back to the nest to take his or her turn. If the nest is left unguarded, even for minutes, predators may home in, stealing or breaking a few eggs. Almost every nest suffers losses.

This constant preying on eggs is what ultimately makes communal laying pay off for the major hen and her cock. If they had only their own eggs, with no minor hens laying, any egg taken by a jackal or other predator would be one of their own. By accepting minor hens' eggs, the pair protect their own; if a predator takes an egg, it is less likely to be one of theirs. This behavior increases survival by the principle of dilution. A similar principle applies to some other species, for example, the huge calving herds of wildebeest and barren ground caribou. By associating her calf with hundreds or thousands of others of the same age, a cow reduces the chance that it will be killed by predators. This rule explains why ostriches, both in communal nesting and in crèching, appear to be altruistic. In reality, the parents are protecting their own eggs and chicks from predation by caring for the eggs and chicks of others. In the long run, the ostriches that practice communal breeding increase their numbers more rapidly than the few that breed alone. Thus throughout their range, most ostriches breed in great loose colonies that make communal nesting and crèching possible. Sound reproductive strategy underlies the sight of a wary adult pair shepherding dozens of chicks across African savannas. □

Natural Bonsai of Sunset Crater

A tiny moth prunes piñon pines into bizarre shapes and incidentally creates good habitat for wildlife

by Susan Mopper and Thomas Whitham

When plants and insects get together, the role of host can often become unpleasant. The trees that host gypsy moths, for example, are weakened and sometimes gnawed to death by their guests. But although hit-and-run tactics of many insects often devastate local vegetation, not all insect herbivory is destructive of the ecology as a whole. On Arizona's Sunset Crater, 200-year-old piñon pines bear the marks of a lifetime of hosting tiny moths that shape the forests they live in. These marks could be viewed as the cruel scars of incessant attack, but as the invading moths have become permanent players in the piñon wildlife community, they have made some surprising and positive contributions to local ecology.

Named for the red glow of its rocks, Sunset Crater is a classic example of a cinder cone and the most spectacular of four hundred such dormant volcanoes in northern Arizona. The crater is 1,000 feet high, with its base about 6,000 feet above sea level. Cinder cones form when molten rock and smaller ash and cinder particles are discharged upward and accumulate into a cone-shaped structure as a volcanic eruption progresses. When Sunset Crater erupted about A.D. 1064, lava flowed from its base, and off and on for the next two hundred years, the volcano rained ash and cinders over eight hundred miles of surrounding terrain. Today, the jagged black rocks of the solidified lava fields are nearly devoid of vegetation, but the cinder soil, which ranges from twenty to several hundred feet in depth, sustains a diverse plant community.

On the Sunset Crater cinder fields, piñon pine and juniper grow at lower elevations (up to about 6,000 feet), while stands of ponderosa pine tend to dominate at higher elevations (to about 7,000 feet). Rabbit bush, hedgehog cholla, Apache plume, Indian paintbrush, aromatic sumac, Mormon tea, and other chaparral shrubs grow among the conifers.

Four years ago, we visited Sunset Crater on a routine plant ecology field trip from Northern Arizona University. As we hiked into the cinder fields we were surprised to find half of the piñon pines stunted. These dwarfed trees looked like

Sunset Crater National Monument
David Hiser; Photographers/Aspen

Piñon pines bear both female and male cones, below (left and right, respectively). A tiny caterpillar, right, feeds within the succulent shoots of the upper tree. The pruning of the canopy eliminates the top shoots, which produce female cones, and stimulates the growth of side shoots, which carry male cones. Eventually the piñon undergoes not only a change in shape but also a sex change, becoming wholly male and producing no seeds.

Photographs by Susan Mopper

bonsai creations and were often no more than half the size of the tall, open-canopied normal piñons. We became concerned because we knew that the piñon pine is the linchpin of the Sunset Crater wildlife community. A piñon seed is one of the largest and most nutritious of all pine seeds. Many of the animals in the piñon woodland are in some way dependent upon the seeds for survival, as until recently, was man. Native Americans have long harvested piñon seeds, and many families still collect seeds for food and currency. Piñon jays, Clark's nutcrackers, scrub jays, Steller's jays, plain titmice, and rufous-sided towhees are all seen among the piñons, feeding either on seeds or on insects found within the canopy. Piñon mice and ground squirrels cache piñon seeds, which account for a large proportion of their diet. In turn, coyotes, hawks, and other carnivores depend upon the small mammals and birds for food.

Since damage to the piñon pines could clearly spell danger to Sunset Crater's ecological system and since there had been no scientific report of this discrepancy in piñon sizes and shapes, we decided to investigate the phenomenon. Upon examining the trees, we noticed that some were infested with a small caterpillar. Our first step was to collect and identify the insect. We shipped some to Canada, where they were identified as *Dioryctria albovitella*, a cone- and shoot-boring moth known to attack only piñons. The moth became the prime suspect in our investigation of the disruption of piñon growth.

In researching the moth's life history, we found that, as is the case with most moths and butterflies, the insect is most destructive in the larval stage. Larvae begin feeding in May and June, boring into and killing canopy branch tips, or terminal shoots, and female pine cones. After four weeks of feeding, the larvae pupate briefly inside the shoot, emerging in July as adults. Females lay an egg on a new shoot bud, and later that summer, the egg hatches, and the tiny larva bores into the shoot, where it lies dormant until the following spring. Then the larva starts to feed, repeating the cycle. Year after year, the larvae kill branch tips, permanently contorting the piñon canopy. The tree responds to the death of its terminal shoots by sending out lateral buds, much like a yard shrub that has been pruned. Some trees lose 80 percent of their terminal shoots to the moth. A stunted, densely branched piñon is one that has been under moth attack for a lifetime.

Moth assault not only alters the shape of a piñon, it is responsible for an even more dramatic change—that of the tree's sex. In piñons, male and female cones grow on the same tree (a condition called monoecism), with male cones on the smaller, lateral shoots and the larger female cones borne on the stout terminal shoots of the upper canopy. In spring, pollen clouds released by male cones cover the tiny, red, year-old female cones, which need another year to mature. In heavily infested trees, however, larvae attack the existing female cones and kill the branch tips that might produce new ones. Since the branch tips are the preferred food of the moth, female cones are destroyed. In the process, the growth of lateral, male-bearing shoots is stimulated. Eventually, an infested tree shifts from monoecism to maleness. Without female cones, no seeds can be produced, and no propagation can take place.

But it isn't enough to know that moths can, in principle, affect piñons. We had to test scientifically whether the moth was indeed responsible for piñon change. We predicted that moth attack of terminal shoots caused the differences in canopy architecture. We then mimicked moth damage for two years by pruning the tips of the terminal shoots of moth-resistant trees. By the third year, lateral buds on the clipped trees had increased significantly.

Clearly, the moth, too, could change a tree that had an airy canopy into a densely branched shrub.

To determine if moth herbivory was affecting the size—as well as the shape—of the trees, we placed expandable metal bands, called dendrometers, around the trunks of twenty resistant and twenty susceptible Sunset Crater piñons of approximately equal age and size. The dendrometers showed that lightly attacked trees grew almost twice as much in circumference each year as did trees with heavy moth damage. Comparing trunk cores and branch cross sections provided further evidence of the moths' restriction of tree growth.

We then selected forty heavily attacked trees of equal age. Twenty were randomly chosen to be sprayed with an insecticide. We treated these trees once a year for three years, then compared them with the twenty unsprayed trees. By the third year, released from the pressures of herbivory, the trees sprayed with insecticide had begun to produce terminal shoots and female cones, while the twenty untreated trees did not. The experiments confirmed that changes in tree architecture, sex expression, and growth were a result of moth attack, not environmental aberrations, heredity, or random events.

Despite the mounting evidence against them, we discovered that Sunset Crater's moths were not the only insects attacking piñons. In fact, the crater's pine trees are also vulnerable to a host of other injurious insects. The piñon needle scale insect, studied by Neil Cobb, a graduate student at Northern Arizona University, is common on cinder-field piñons but rare in trees growing in other soils nearby. Similarly, hundreds of colonies, of up to fifty hymenopteran sawfly larvae each, often defoliate shoots of Sunset Crater piñons but are seldom found on piñons not growing in the cinders. We hypothesized that the poor cinder soil left trees vulnerable to moths and other herbivores. Cinders are much larger than loam, sand, or clay particles. Shallow layers of cinders form an excellent water-conserving mulch, but when deep, as at Sunset Crater, they retain little moisture and few nutrients. To test our hypothesis, we measured tree water stress and discovered that Sunset Crater piñons were indeed far more stressed than their loam counterparts. To test the effect of reduced stress on plant resistance to attack, we added water and fertilizer to stressed Sunset Crater piñons. We found that trees given supplemental water and fertilizer produced significantly more female cones and longer shoots. We began this experiment in 1985, and during the next several years we will monitor the trees to determine the relationship between plant stress and insect attack.

The results of our observations of habitat-induced stress, coupled with the different degrees of insect damage among piñons growing within the cinder fields, suggest that resistance to attack involves both environmental and genetic factors. We are puzzled by the relatively resistant piñons growing next to heavily infested trees. Have these trees adapted to overcome the insect attack and stress they face in the cinder fields? Could they represent a different, more successful race of piñons, genetically distinct from their susceptible neighbors? Do the piñon populations growing on and off the cinder fields represent yet other levels of genetic differentiation? Does adaptation to a stressful environment diminish a tree's ability to resist attack?

Our objective in future work is to separate genetic from environmental influences and then investigate the interaction between them. But we already know that there are some differences between resistant and susceptible piñons. Resin production, for example, is greater and foliage water content is lower in resistant than in susceptible trees, suggesting that resistant trees may be better adapted to the stressful environment. Resin, the sticky, viscous

Sunset Crater piñons support a specialized community of seed-dependent birds and mammals and their predators. Animals such as the piñon mouse, below, which gather and cache piñon seeds, benefit from a reliable annual cone crop. Moth-attacked and healthy piñons grow side by side at Sunset Crater, right. The tree at the left, dwarfed by chronic herbivory, is 180 years old; its neighbor but 150.

Both photographs by George H. H. Huey

exudate of conifers, can be a potent defense against enemy infestation. Attacking insects are often smothered by the thick substance. Similarly, insects are more successful when the plant food upon which they feed has a high water content. Piñons with high levels of resin and low water content may be more resistant to moth larva attack, enjoying an advantage over trees lacking these traits. Over centuries, high levels of pest damage will favor the evolution of resistant traits. Piñons inhabiting the Sunset Crater cinder fields have had seven hundred years to adapt to the harsh environment and intense insect herbivory; the observed resistance of some trees may represent a very recent evolutionary adaptation.

Laboratory analyses and field experiments can help us find out if this evolutionary scenario is correct. One way to test the genetic hypothesis is to analyze piñon tissue by electrophoresis. This nondestructive procedure requires only a few piñon needles in order to isolate specific proteins unique to an individual tree and provides information on its genetic makeup. We are also conducting a series of field experiments in which piñons on and off the cinder fields are exchanged and some are grown in common gardens. If the traits of these trees remain constant we will know that genetic differences exist. We hope to graft piñons from small shoots taken from resistant and susceptible trees. If there are genetic differences, we expect to see that trees grafted from resistant trees retain their resistance to insect attack.

Meanwhile, we regard our investigations as already having borne fruit by providing us with a major surprise. At first, we thought the destruction of piñons by moths and the subsequent reduction of female cones must adversely affect Sunset Crater wildlife. But research in progress by Kerry Christensen of Northern Arizona University suggests a more complex scenario. Some wildlife may indirectly benefit from the moth's activities. The piñon pine is a masting plant; that is, cones are produced abundantly in four- to seven-year cycles. A mast year of high cone production is often followed by several years of low cone crops. At Sunset Crater, heavily infested piñons never produce female cones, and lightly infested trees do not mast at the intensity of piñons growing off the cinder field. The energy conserved by not masting, however, allows a consistent yearly production of cones by trees with few moths, thereby providing a continuous food supply to the community.

Because a low but continuous food supply may be important in supporting small mammals dependent on piñon seeds, the indirect effects of the moth may make the environment more suitable for small seed-eating mammals. Our comparisons between seed production of Sunset Crater piñons and the nearest, similar-aged, loam piñons support this theory. In three out of the last four years, Sunset Crater piñons with relatively little moth damage produced substantial cone crops. Yet in only one year of the last four did the nearby loam piñons—which are virtually uninfested—produce cones. This difference in seed production between sites affected the populations of small mammals. The den-

sity of the piñon mouse population at the cinder-soil sites was more than twice as high at Sunset Crater than at adjacent areas having other types of soils. If this unexpected result is confirmed by future research, it will demonstrate how the moth, a seemingly destructive herbivore, can have a benign effect on at least some members of the ecological community.

Moth-induced metamorphosis of piñons from trees into shrubs has other unexpected consequences for the community as well. A shrublike canopy can be a favorable environment for many animals. Denser canopies harbor more insects than do the typical, open piñon canopies. This serves to lure insectivores such as rufous-sided towhees, plain titmice, burrowing owls, and mountain and western bluebirds to the area. In addition, the thick canopy of susceptible piñons protects small mammals and birds from attack by great horned owls, sharp-shinned hawks, and red-tailed hawks, the dominant predators at Sunset Crater. The wildlife population of Sunset Crater may therefore be equal to or greater than that of other piñon woodlands.

The actions of a nondescript moth produce effects that reverberate throughout the Sunset Crater ecosystem, revealing how genetics and environmental stress influence plant resistance and susceptibility. The indirect effects on other animals at Sunset Crater will help us discover the subtle yet vital threads linking all members of the community. But perhaps most important of all, these moths serve to remind us not to jump to conclusions based on human prejudice against insects. As ecologists recently discovered in studying the effects of naturally induced forest fires, some phenomena that appear on the surface to be destructive often have a hidden positive effect on balance. □

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At three months, cubs stick close to home, playing together and investigating their surroundings. In a couple of weeks, these three will begin to follow their mother as she leaves on her nightly foraging rounds.

Robin Redfern; Animals Animals

The Case of the Clannish Badger

What juicy tidbits lurk in the shadow of Scotland's milk cows? The badger knows

by Hans Kruuk

The more we tame the landscape, the more we feel drawn to the few wild creatures that manage to hang on. In Britain, the beloved badger is the largest remaining wild carnivore. Throughout England and Scotland, many place-names feature the words *badger* and *brock* (dialect for badger), conservation societies use the badger as a logo, pubgoers quaff Badger Beer, and any naturalist worth his salt will have spent many evenings near a badger sett, or den, watching the cubs play. Even people with little interest in nature are familiar with the badger's striking black-and-white face and may have caught glimpses of the animal in woods and copses throughout the gentle countryside. Touch badgers and you touch a nerve of the nation: government committees will be organized to look into the matter; newspapers will report on the uproar.

And yet, despite the special place the European badger (*Meles meles*) holds in the hearts of many Englishmen, the animal has not been exempt from harsh treatment. Every year a certain number are illegally dug out of their burrows or cruelly caught in snares and later set upon by dogs. And some years ago, the badgers found themselves in an even worse spot: they were discovered to be suffering from, and presumably infecting cattle with, bovine tuberculosis. Cattle had to be slaughtered, and farmers and veterinarians clamored for tough controls. But how to deal with the crisis was unclear because despite all the earlier attention lavished on badgers by naturalists, few facts were known about the ecology of this highly nocturnal animal: about its numbers, social organization, diet, or even how much contact it actually had with cattle.

Britain's badgers interested me because their social life differed remarkably from that of gregarious carnivores I had studied before. In Africa, for example, living in groups is of obvious benefit to carnivores such as lions and spotted hyenas because it increases their chances of successfully pulling down large prey. Badgers, too, were known to live in groups, but they were thought to sustain themselves on a much tamer diet of plants and invertebrates. If these badgers did not go round in packs, tackling deer or cattle, why should they live in groups? The opportunity to address this question and, at the same time, perhaps contribute to the more practical need for information about bovine tuberculosis led me to devote nearly a decade to studying badgers.

Although badgers belong to the order Carnivora, they have generally been described as omnivorous: wheat, fruits, rabbits, insects, roots, frogs, the list of foods attributed to their diet seems endless. Quantifying just how much of each food type the badgers were eating would have been extremely difficult; fortunately, things were not so bad as they first appeared. When my colleagues and I analyzed scats from our six study sites in Scotland, the most important food item by far turned out to be earthworms.

Watching badgers in the dark, with the hot-eye (a night scope with infrared light), we soon learned how they catch the worms. Walking quietly and sniffing with its nose held close to the ground, a badger gently winds its way across a field until it stops to pick up a night crawler just under its nose. Usually, the worm is simply snapped up and chewed to bits without any trouble. Sometimes, however, if the worm is partly underground, it might take the badger several seconds to pull its prey out, straining as the taut worm resists. Several species of worms live in badger territory, but with few exceptions, badgers eat only the largest, the night crawler *Lumbricus terrestris*, which can be more than six inches long. Night crawlers are the mainstay of the badger's diet, and as I was to discover, quite a bit about the badgers I studied can be explained by their predilection for worms.

We chose our study areas to reflect the diversity of habitats found in the Scottish countryside. One was on acid moorland, with few trees and little grassland; others were on agricultural land mixed with coniferous or deciduous woodland; some were on very rich soils; some on poor. The differences in habitat were spectacular, but that did not show in the badgers' diet: in all places, at all times, earthworms predominated, as shown by the large numbers of chaetae (worm bristles) and earth-

Occasionally, rather than simply sniff along the ground for worms, a hungry badger will turn over a rock, below, especially in dry weather when worms are less likely to come aboveground. Badger setts, top right, are large underground burrows, commonly consisting of a network of tunnels with six or more entrance holes. The badgers' prodigious digging skills are evident in the impressive piles of earth deposited in front of each hole, generally on the downslope side. After gathering a ball of dry grass, the female, bottom right, will drag it backward into the sett, where she will use it to freshen up her bedchamber.

Martin B. Withers; Frank Lane Picture Agency

worm gizzard rings in the feces. Other foods were also taken: beetles, oats, barley, a small tuber called pignut, rabbits, frogs, carrion, fruit, some fungi. But these were minor items, taken when chance presented them. We measured the availability to badgers of these different foods, per area or time of year, and for all of them we found a good correlation between what is there and what the badgers eat—for all, that is, except earthworms. The proportion of earthworms in the diet is more or less constant, regardless of the climate, weather, habitat, and even (up to a point, of course) how many there are. In other words, badgers concentrate on catching earthworms, and if worms become temporarily scarce, they merely change feeding tactics. Rather than switch to a different prey, they walk longer distances to find worms or simply eat less for that period.

Most of the time, however, the badgers have little problem finding enough worms to fill their stomachs. The size of earthworm populations in Britain can be staggering, especially in rich soils, such as those fertilized by cow dung. As a rule of thumb, one reckons that on any given pasture, earthworm biomass is about the same as that of cattle, and areas with 1,100 pounds of earthworms—most of them *L. terrestris*—per acre of pasture are by no means unusual. Interestingly, earthworms have about the same chemical composition as prime beef and are a potentially rich source of protein, so it is perhaps remarkable that not many more species of animal have developed a taste for them. Moles, hedgehogs, various birds, and the odd fox prey on worms, but by and large, they have relatively few enemies.

One reason may be that worms are often difficult to get at. Night crawlers live in vertical burrows deep in the soil. On suitably damp, still nights, they emerge, and with their tail end safely in the entrance of the burrow, they pull in leaves and grass to feed on later. Disturbed, night crawlers withdraw in a flash; to catch them, badgers have to be fast. Also, in areas of dense, high vegetation, the worms' ability to detect vibrations in the grass alerts them to approaching danger. For the badgers, this means that while some worms can be caught on the forest floor, the most profitable terrain for hunting worms is short-grass pasture. And that is where badgers meet cattle.

Badgers spend hours zigzagging through fields, walking close to resting cows or sheep, seemingly oblivious to anything but worms. They are often hugely successful, catching hundreds of large worms each night. Foxes, which also frequently eat earthworms, sometimes walk behind foraging badgers, taking advantage of their skill at finding rich patches of worms. If a badger notices a fox nearby, it usually makes a dash after its lighter and more slender competitor, but foxes are nimble enough to stay out of harm's way.

There would be little trouble between badger and farmer if it were not for bovine TB. Badgers may do some damage to fields of corn, wheat, or oats, and rarely, an odd rogue will kill a lamb or get into a chicken run. One can live with that. But TB is different. TB has been eradicated from most British cattle herds, with the occasional case arising from imported animals. But in parts of southwestern England, the disease persists, at a level up to ten times the national average. Even the most ardent conservationists agree that badgers are likely to be involved, although the animals have been found guilty only by association.

In areas where bovine TB exists, there may be up to sixty badgers per square mile; one of every six animals has been estimated to carry the disease. Badgers infect each other (although it is not known how they first got the disease), and once an animal has tuberculosis, it may survive as a carrier for a year or more. As sick badgers feed next to cows, they leave urine and droplets of sputum full of *Mycobacterium bovis* on the grass, where grazing cows presumably pick up the bacillus. Whatever interspecific contamination occurs, it is likely to be a one-way process; cattle herds are tested so often that TB is usually detected long before an afflicted individual becomes infectious.

Not surprisingly, a farmer who has had to slaughter some valuable cattle and then finds a TB-riddled badger staggering in his field needs no more proof. He demands action. And until recently, he has gotten it. Over a period of about six years, officials of the Ministry of Agriculture gassed many thousands of badgers in their underground holes. Conservationists have been in uproar, and there have been two official inquiries. Meanwhile, the whole effort appears to be rather ineffective; the incidence of TB in cattle has decreased somewhat, but not much. Under pressure from the environmental lobby, the antibadger campaign is now being scaled down, and

Michael Leach; Natural History Photographic Agency

John Lynch; Survival Anglia

badgers are now trapped, instead of gassed, and then only in really hard, uncontroversial cases.

Why measures to control the disease in badgers (and therefore cattle) have failed is still unknown. Quite likely, the inefficiency of the gassing method comes into it, but other factors, too, must be important. To appreciate exactly what is involved in this kind of management situation, the social organization of the species should be taken into account.

Probing into the social life of shy, nocturnal animals is hard. Badgers, furthermore, are difficult to recognize individually and often spend their active hours moving about in thick woodland. They are, however, easy to catch in cage traps. Badgers will do almost anything for a peanut, so all one has to do is run a line of peanuts across a badger path and into a trap; the next morning, one in three traps will have a badger in it. In that way, my students, colleagues, and I put radio collars on almost a hundred animals in the study areas and tattooed a number in the loin (which is hairless). On the radio collar, we also put a small "beta light," which glows in the dark. This made it much easier to find the animal in the pitch dark and then watch it through the hot-eye.

Over the years we have spent many hundreds of nights following and watching the badgers. They appear to live in groups, or clans: some with only a few animals; some with a dozen or more. Generally all animals from one clan use the same territory, within which are a number of holes, where the badgers sleep in the daytime and where they have their cubs; these are their setts. Usually there is one main sett. The largest main setts consist of a network of tunnels, altogether sometimes several hundred yards long, with many chambers and forty or more entrances. But most main setts are smaller than that, with half a dozen entrances, mostly connected underground, and huge spoil heaps in front of them. The chambers in the setts contain bedding, dry vegetation—often in sizable quantities—dragged in by the animals. To watch a badger at work is intriguing: it collects a large quantity of plants, scraping them together into a heap, then puts its forelegs over the mass with a little pounce and drags the whole thing backward to the sett, maybe a hundred yards or more, sometimes overshooting the entrance and having to turn around again. These main setts are always in use, some by generations of badgers over centuries; the animals spend the winter there, and depending on the weather, they may not come aboveground for days or weeks.

In addition to these main setts, there are outliers, which usually have a single entrance and are used only part of the time. The animals that sleep there most often are the younger, subordinate members of the clan. These individuals, which may be male or female, spend time at the main sett as well, but generally speaking, socially peripheral badgers use the main sett less often than do the more dominant animals. And this is important in the context of the TB campaign: control efforts focused on the main setts because they are easier to find, and yet a badger wasting away with TB may well be a pariah and thus more likely to sleep in outlier holes not reached by the gassing and trapping.

Whatever the reasons for the lack of success, the badger eradication campaign appears to be on the wane. The Ministry of Agriculture now plans to continue research on how TB is transmitted, on immunization, and other possible ways of tackling the problem. Once again, the bludgeon has not proved a satisfactory answer to an ecological problem.

When following badgers fitted with radio collars, both within and far from TB-infected areas, I noticed large differences in both the size of the clans and the size of the areas used by various clans. Intriguingly, my early observations suggested that the bigger clans did not necessarily

occupy the largest areas. My original question, why do badgers live in groups? had to be refined, replaced by a more exact one: What factors affect group and territory size? To answer this question, I needed to combine my findings on the badgers' diet with more information on range and clan size.

Using radio tracking, measuring ranges should have been a simple affair. With badgers, it turned out to be a long-drawn-out, labor-intensive business, largely because of the way badgers move through their territory. After emerging from their setts some time after dusk, they generally walk a good distance until they reach a suitable feeding area, usually a small patch rich in worms. They may spend hours there, then perhaps return or go to another patch. During any one night, only a small part of the range is covered, and only after many nights of following the animals, stumbling around in the dark, could a researcher determine the whole range. Fortunately, I found a shortcut.

Badgers have long been known to defecate in special sites. These latrines are conspicuous groups of small pits, each with a scat in it, usually sited near some landmark, such as a woodland fence or an especially large tree. There is often one latrine next to each sett, but radio tracking revealed that most of these scent-marking stations are placed on the edges of the range, where they undoubtedly serve to announce territorial boundaries. Once again, peanuts came in handy. Peanut bait, placed on the setts and laced with pieces of colored plastic, was readily consumed. The next morning, plastic pieces showed up in the latrines. By using different colors for different setts, I could map the territorial configuration of several clans within a few weeks.

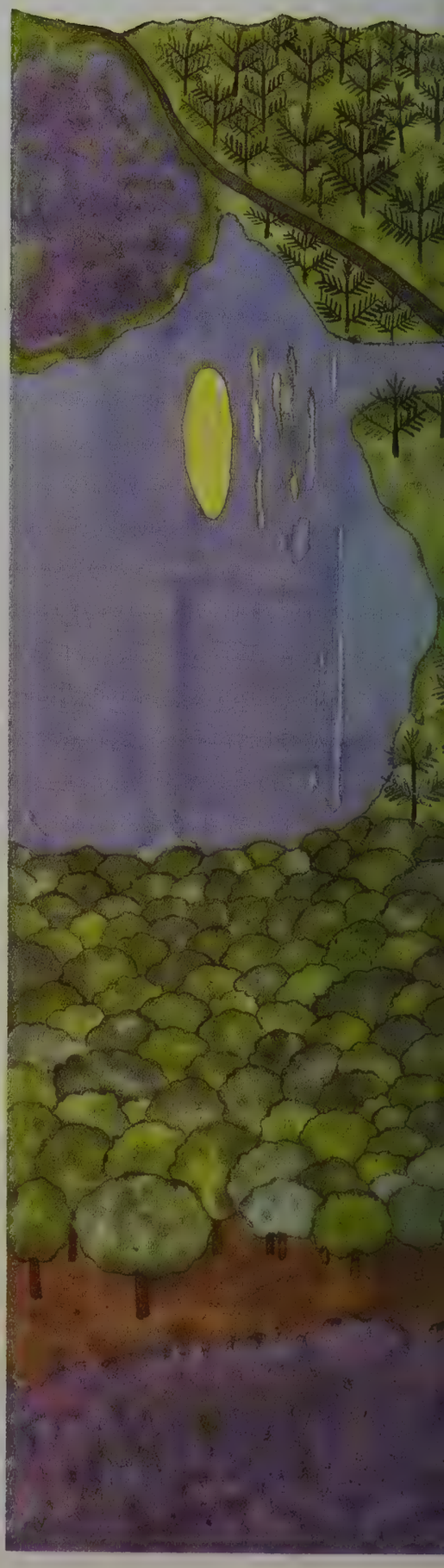
This bait-marking method, together with the radio tracking, quickly settled the question of range size. The variation was, indeed, huge: the smallest range was about 50 acres, the largest 3,700. The average range in Scotland was about 300 acres. The average in England, where badger populations are denser, is on the order of 125 acres.

Finding out how many badgers actually lived in a territory was much harder. Although badgers are relatively easy to watch on their setts, counting them there is difficult. For one thing, one range may include many setts, and each sett most likely has more than one entrance hole. For another thing, periodically throughout the night, as some badgers return to the sett, others go out—perhaps for the second time. Here again, we made use of scats to make an estimate (it is remarkable how often a mammalogist is reduced to studying scats), this time with the help of a radioactive isotope.

In each badger clan, we injected some animals with a small dose of Zn^{65}, a harmless isotope of zinc that is also used for medical purposes. For the next two months, the feces of these injected badgers could be recognized with a scintillation counter, enabling us to calculate, for each clan range, what proportion of feces, and therefore badgers, contained the isotope. Since the number of injected animals was known, we could estimate the total number of badgers in the clan. The smallest number we found was one, the largest twelve, but even larger group sizes are known from elsewhere.

Comparing clan size to territory size, I was immediately impressed by the striking lack of relationship between the size of a range and the number of badgers living in it. Some large clans occupied huge ranges; others seemed to do fine on small ranges. Similarly, some small clans had large ranges; some, small ones. Something in the animals' environment was determining the size of their ranges, and something quite different was determining group size. To find out what the two factors were, I started to look at the badgers' food again, especially, of course, at earthworms. In principle, determining the density and biomass of earthworms in an area is fairly easy to do by pouring a weak solution of Formalin on the ground and then counting and weighing the numbers of worms that come up to the surface. In actuality, it is a slow, tedious, and laborious job, but it is effective, and in the end it proved to be worthwhile.

We soon found that there is a simple correlation between the biomass of earth-



n the Scottish countryside, a badger clan's territory usually encompasses several ypes of vegetation: deciduous and coniferous woods, moorland, fields of crops, and asture. In the course of a night, badgers may cover several parts of the territory in earch of food, but worms—their favorite food—are most plentiful in the pastures. There, noses to the ground, oblivious to all but the pursuit of their prey, the badgers ingle with resting cows. When not out foraging, the animals return to sleep in the ain sett, here visible as a cluster of holes to the left of the cow. Territories often also ave one or more outlier setts, which may consist of a single hole at the base of a large ree. Younger, socially subordinate animals most commonly sleep here; badgers eakened by TB may also use these isolated holes.

ank Bozzo

A. Davies; Bruce Coleman, Inc.

Having called her five-month-old cub to the surface with soft, grunting noises, the female, below, has just delivered a small piece of carrion. She may continue to offer such serendipitously found treats to her cub for a short while, but soon, this young badger will be fully weaned and foraging entirely on its own. Male badgers—distinguishable from females by their broader faces—are usually the first to emerge from the sett in the evening, right. They may hang about for quite a while, scratching and grooming themselves, before taking off on a night of worm hunting.

Hans Kruuk

worms in an area and the number of badgers living there: the more worms, the more badgers. What, then, determines the size of the range? The answer to that question could, perhaps, have been dictated by common sense; it seemed so simple, once we began to see how it all worked. Most likely, the badger territory is determined by the distribution—rather than the density—of worms. More abundant in some habitats than others, earthworms are especially highly concentrated on pasture land. Also, as we've seen, although worms are found in other environments as well, they are easiest to catch on short, grazed grass. In Britain, however, pastures tend to be rather small, often separated by woods and moorland, and not all pastures are grazed simultaneously. Furthermore, different microclimates bring out the worms on different nights, so the badgers need to have access to several pastures or other worm-rich patches. The distance between these patches, then, is what dictates range size.

The presence of several separate, often massively rich worm patches also helps explain the badgers' social system. Most mustelids, such as the American badger (*Taxidea taxus*), live solitary lives, with females occupying more or less exclusive ranges, overlapped by those of single males. The European badger has a quite different setup. Within each clan, often (but not always) only one female, the dominant sow, reproduces, and there is one dominant male, the boar. The other badgers tend to be the offspring of this pair, and they stay in the range for a long time, often many years, without reproducing. (Badgers may live for twenty years, but in nature, an animal is very old at ten.) I knew several females that died old, in their natal range, probably without ever producing cubs. By comparison, most males will emigrate at some stage, but often not until they are several years old (they are sexually mature by the age of one). If and when they emigrate, the males probably go no farther than a neighboring clan, and even then probably only when there is a vacancy for a dominant animal. So it appears that a badger stays at home and keeps tabs on the clans next door, aided perhaps by the elaborate system of border latrines. Females do not leave, although they may sometimes expand their range, spilling over onto a neighboring territory. Basically, however, they do not breed unless a vacancy opens up at home. None of these grownup offspring assist with rearing the dominant sow's annual litter of cubs; they are just sitting tenants.

Were it not for the patchy distribution of their favorite food, the dominant badgers might not tolerate the presence of so many offspring. As it is, however, the animals need not get in each other's way most of the time, but at some point competition may arise. Many badgers are scarred. There is a ranking order among males and one among females, and badgers will fight, sometimes with fatal consequences. Intraclan aggression is related to the amount of food available, and if that aggression affects mortality or emigration, which is likely, then it could also explain why the number of badgers in an area is so closely correlated with worm biomass.

All this suggests that the main biological function of the badgers' group organization is that it allows animals to hang on at home until a suitable vacancy presents itself. Badgers are fiercely territorial and vacancies are few, so it presumably would not do for a badger to just start roaming around when sexually mature. When I introduced a strange animal, male or female, into a seminatural group of captive badgers, it was inevitably killed by the dominant of the same sex.

It could be argued that the clan system of the badgers in the British Isles is dependent upon the agriculture there. And indeed, in Italy, where the agricultural system is different and worms less common, badgers live on a more varied diet of insects and fruit (in some places, mostly on olives), and are much more solitary. Similarly, when the density of earthworms dropped in one of my Scottish study areas, probably because of agricultural changes, badger clans began to disintegrate, with individuals living more or less solitarily, but still within the clan range. This new arrangement approached the traditional mustelid pattern of social organization.

But if the badgers I studied have turned out to be flexible in their social habits, perhaps the same will be proved true for some of their relatives. The European badger and the American badger, for example, are sometimes compared: the former described as a social creature; the latter as a solitary specialist adept at catching squirrels and gophers. But who knows what might happen if the American badger discovers an agricultural source of food, such as the lowly earthworm. □

Figures in a Nativity scene carry one family's hopes for a prize in Oaxaca City's December 23 competition of radish sculptures.

Night of the Radishes

Mexican families cultivate freak forms of the once-alien vegetable to create holiday tableaux

Text by Gary N. Ross • Photographs by Serge Hambourg

In Oaxaca City, the capital of one of the predominantly Indian states in the south of Mexico, there is a continuous round of merriment from Guadalupe Day on December 12 through Kings Day on January 6. The heart of this time is La Noche de Rabanos (night of the radishes) on December 23. On this night the Oaxaqueños display sculptures built from the fleshy roots of the radish plant and arranged in miniature scenes frequently embellished with dried flowers, fresh fruits, leafy vegetables, and colorful doll clothing and accessories. Where possible, the designers choose grotesque roots that naturally convey the human, animal, plant, or inanimate forms they envision. The radishes, usually red but often white as well, range from minuscule to nearly two feet long. Increasingly, for added realism, roots are modified by cutting or scraping and smaller roots or slivers secured to them by toothpicks.

The tableaux range from exalted portrayals of biblical texts and storybook fables to whimsical vignettes of secular life (sometimes featuring figures whose crudely executed anatomies border on the indecent). Although most themes are familiar and easily recognizable, many are titled, sometimes with original lines of prose or poetry. The crowd-pleasers are the Nativity, the Inferno, the Flood, and the all-time favorite, the *posada*—a type of procession, symbolizing Mary and Joseph's search for lodgings in Bethlehem, in which people wander through town knocking on doors.

Some thirty tableaux are displayed in makeshift booths set up on the street fronting the Governor's Palace, which sits on the south side of the *zócalo*, the city's main square. Each stall is identified by number and family name, since prizes are awarded for what the city-sponsored judges consider the most extraordinary arrangements. As the evening progresses, family members stand behind their creations, entertaining questions and comments from the steady stream of spectators, who often lay wagers on possible winners. At nine o'clock, first-, second-, and third-place cash prizes of up to $500, along with certificates for honorable men-

Emiliano Zapata, left, the revered Mexican revolutionary folk hero, and his brave band of hombres are reduced to fiery radishes; their slogan, "Land and Liberty," lives on. Thousands flock to see the display booths in front of the Governor's Palace, below, located on Oaxaca City's main plaza.

tion, are presented by the governor himself in a public ceremony in the palace. Several families have over the years become local celebrities and invariably surface among the winners. The Gomez family usually places, and in 1985 the Garcia-Esperanza family walked away with three of the four winning entries. The winners attach their ribbons to their exhibits for all to note, and spectators jam the street to obtain a second glance.

The climax of the night, between eleven o'clock and midnight, is a fireworks display, to which the crowd responds with raucous appreciation. At midnight, all activity ceases. Each scene is disassembled and taken home by its creator or by a local admirer, who may have paid a day's wages to possess such a masterpiece. With frequent sprinklings of water, the works can be kept fresh for several days, to become conversation pieces for the remaining holiday festivities. Eventually, the various tuberous gods and demons, palaces and stables, folk, horses, sheep, dogs, and sunflowers wilt and shrivel into unrecognizable forms and have to be discarded.

The radish was introduced into the New World shortly after the Spanish conquest in the early sixteenth century. A member of the mustard family, the plant was probably domesticated in China and has been a common, highly adaptable garden cultivar throughout Europe and Asia for at least 2,000 years. The roots vary in shape from spherical to long cylindrical or tapered. They may be white, pink, red, purple, or even black—the reddish types being less pungent than the white. The largest forms are biennials; the smallest, annuals. They propagate by tiny seeds and grow best in temperate climates where soil moisture and texture tend to be fairly uniform. There are both spring and winter varieties; the latter, which are frost resistant, mature more slowly but attain greater sizes since they have a longer growing season. The winter types also have firmer flesh and are easily stored.

The extensive Oaxacan Plateau (governed originally by the Marqués del Valle, Hernán Cortés himself), with its mild climate, was perfect for many of the introduced Old World truck crops, including the winter radish. The tangy root—high in vitamin C, iodine, and bulk; low in calories; and reputed to cure respiratory ills—soon became the most prized vegetable in the Indian and mestizo cuisines, and the principal ingredient in a regional version of *gazpacho*, a fresh salad. This *gazpacho* (which in Oaxaca also includes lettuce, cabbage, and beets) and a stew concocted from the bobo fish (Pacific threadfin) evolved into the traditional dishes for the Cena de Noche Buena, a sumptuous feast served at midnight on Christmas Eve to commemorate the birth of Jesus. This feast has been the most important family celebration in the state of Oaxaca since the sixteenth century.

Because of the indigenous people's (principally Zapotec Indians) reverence for the land, however, fields were not prepared as were their counterparts in Spain. Harrowing was avoided in order not to offend the gods (pulverizing the soil was considered a desecration). Instead, the fields were simply broken either by hand or with ox-tethered wooden plows. Since Oaxaca is a land of mountains, rocks abound, and these were usually left in the fields.

The lack of abundant water—the plateau receives only about twenty-one inches of rainfall annually—generally made irrigation unfeasible. The adaptable radish, however, pushed its tender, pliable, but determined root system into the cracks between the hard unbroken clumps of earth resulting from cursory plowing and into the hairline fractures between the hard earth and the rocks. The resultant vegetable, as robust as any typical radish, was contorted and misshapen. In the past, and still often today, the farmers attributed this outcome to some diabolical defilement. In any case, they appreciated the results.

The odd and often vulgar-looking curiosities became instant hits in the open-air market held each Friday in the region's center of commerce, the central plaza of what is now Oaxaca City. There, produce from throughout the plateau and surrounding mountains was brought for display and trade. According to Zapotec folklore, the imaginative Indian children, who lacked formal toys, rapidly took to the radishes' appealing shapes and created their own personalized playthings—people, animals, plants, houses, stables, and so on. The parents, too, soon became involved, and a friendly competition developed as families sought out the most bizarre-looking roots for a moment of

A radish populace, left, commemorates Good Friday at Santo Domingo Church, built in Oaxaca City in the sixteenth century. Providing a counterpoint to such Christian motifs, an Aztec priest, below, prepares to sacrifice a tuberous maiden.

lighthearted jest or mockery. Each week, the Friday market revealed new surprises. The radish had become an endearing commodity to the Zapotec people.

Although radishes could be harvested during all twelve months of the year on the plateau, the main harvest for other vegetables—squash, beans, and corn—was in early December, just before the Christmas season. Fresh wildflowers (especially orchids and bromeliads) and various kinds of greenery, such as mosses and lichens, collected by Indians from the moist eastern mountain ranges, were also on sale for use as house decorations and as backdrops for Nativity scenes on home altars. Merchants purchased the most outlandish-looking radishes and displayed them in their shop windows not only to amuse but also to lure passers-by. Competing merchants paid the Zapotec farmers well for just the right radish to complete an imaginative scene. All produce had to be sold by closing time on December 23, and customers vied for the opportunity to purchase the radish displays.

Over the years, the city's southern periphery, near the plateau's only permanent source of surface water, the Rio Atoyac, became the center for the cultivation of vegetables and flowers (the latter adorned church altars and grave sites, particularly during the November celebration of All Souls' Day). There, because of the relatively high water table, the radishes flourished and the small farms became the core of two larger haciendas—La Noria (The Well) and La Trinidad de las Huertas (The Holy Trinity of the Orchards). As the city expanded, the central marketplace enlarged and fragmented, with the floral and vegetable components constituting a new "radish market."

December 23 became the foremost market day of the year in 1825, when a priest in Oaxaca City instituted the practice of fasting on December 24 in preparation for the Cena de Noche Buena at midnight. This market day became known as the great "Abstinence Day Market." La Noche de Rabanos, however, is the legacy of Don Francisco Vasconcelos Flores. Born in 1837 into a family of meager means, Francisco was apprenticed at an early age to a shoemaker. This experience led him in later years to champion the cause of dignity for his fellow craftsmen. In August 1872, he was instrumental in organizing 300 artisans into the Sociedad Mutualista de Artesanos. In October 1888, the society organized an exhibit of artistic products that included ornamental vegetables and flowers. And on December 23 of the following year, the society's exhibit focused on the curious radishes, which along with dried flowers (*flores immortales*), were arranged into sculptural settings. The displays, assembled on small handmade tables and canopied with fragrant branches of laurel and pine, were set out in the central patio of the Governor's Palace and throughout the *zócalo*. La Noche de Rabanos was born.

After 1889, the celebration wandered about the city: in 1892, to the Porfirio Diaz Market; in 1907, to the Carmen (also called the Sanchez Pascua) Market, which was inaugurated on December 23 with advertisements proclaiming "elaborate radish displays at night." Eventually,

An eagle grasping a snake, below, evokes the mythical founding of Tenochtitlán, the capital of the Aztec empire and now the site of Mexico City. One of the three Magi, right, embodies the current trend in assembling radish sculptures: in years past, tampering with the natural protuberances of the naked vegetable was frowned upon.

the celebration returned to the popular *zócalo* in order to take advantage of Oaxaca's burgeoning tourist trade.

Meanwhile, the city continued to grow. Farmlands were engulfed, and the land reforms of the revolution in the early 1900s dismantled the hacienda system of ownership and operation. The result was the redistribution and urbanization of the former rural lands. The two large haciendas on the city's south side were reduced to grids of short streets stippled with small single-family houses. The newly formed neighborhoods were denoted on maps as Colonia La Trinidad and Fraccionamiento José La Noria and streets were named to reflect the residents' former sources of livelihood: Lemon Orchard, Orange Orchard, Olive Orchard, Laurel Orchard, and Flower Orchard. Indeed, many tenants continued to cultivate market produce in their individual backyards and founded local guilds to assist with their specialized problems.

This new era of the minifarm initiated an unexpected bonus in radish agriculture. Instead of being subject to the whims of nature and diabolical gods, the growth of the fleshy roots could now be supervised. Cultivators periodically hand watered the plants from wells and coaxed the roots into irregular shapes within rocky beds. Once again the Zapotecs had lucked into a winning combination.

Then the unexpected happened. The population expansion throughout the plateau, with its consequent deforestation, disrupted the environment: the climate became more arid, the water table began dropping a foot or more each year, and the Rio Atoyac ceased to flow except for a brief period in the shortened rainy season. Agriculture became more difficult and less dependable. The specialty radishes grown in the small backyard plots began to suffer, too. Their smaller size and reduced protuberances discouraged exhibitions. By the late 1940s and early 1950s, individual displays fell from nearly 200 to a mere handful. To compensate, the radishes' individual roots were modified. Although such remodeling had previously been discouraged, the artisans now skinned, scraped, sliced, and reassembled the radishes into clever sculptures and scenes. The public was at first dismayed, but the novel artistry soon charmed the spectators, and a new twist was added to the quirky La Noche de Rabanos.

As a further incentive to participation, in the early 1970s, the state tourist commission established simple rules for the contributors and pledged to award prizes, ribbons, and certificates for the best displays. The contest was even broadened to include awards for sculptures of *flores immortales* and of *figuras de totomaxtle* (simple creations of dried corn husks, originally invented by the farmers as cheerful, make-do Christmas gifts for their children). These are neatly aligned on the other side of the street from the radish displays. The new arrangements have met with the approval of both locals and tourists, who can share in an occasion that makes no controversial social, religious, or political statements. La Noche de Rabanos is a simple expression of amusement, celebrated on a day of convenience—a true fiesta! □

Winter hurricanes in northern waters appear with little warning. High winds and heavy seas threaten fishing vessels and oil company rigs.
Tony Stone; Worldwide

Hurricanes of the Arctic Night

What's as cold as a williwaw and as quick as a willy-willy?

by Bruce Stutz

Although there were few ancient accounts of voyages in arctic seas, there was no lack of speculation among the people of the Mediterranean regarding the "congealed waters" of the far north. Here, the Greeks were told, there was no longer any distinction of land or sea or air, but an impenetrable mixture of the three where the gods forbade mortals to see the boundaries of things. Pliny called these waters "accursed by nature and shrouded in thick darkness," the "chilly hiding place of the north wind."

North winds in arctic seas still blow no good. They make fishermen and oilmen in Nordic seas or off the coast of Alaska especially wary, on the watch for the sudden winter storms they call big blows but which meteorologists now concede are arctic cyclones, often equal in intensity to tropical hurricanes. The reports of those who have been through an arctic hurricane make the "hideous sea hounds" that took hold of ancient ships seem tame.

Brad Matsen worked on fishing trawlers in the Bering Sea. "In the midst of the storm," he says, "the clouds are so low and the snows so heavy the bright halogen lights on the boat deck create a glow beyond which nothing can be seen." So the fifty-foot waves appear suddenly, black walls of seawater that crash over the boat and crumple the steel plate hull. "All you can do," explained Matsen, "is try to stay with it. Keep the engines up and bow into the waves and wind."

The winds in an arctic cyclone can gust to a hurricane force of more than sixty-four knots. Most modern ships can bear up under the buffeting, but spray from the chaotic seas often freezes on vessels' rigging, making them top-heavy. Ice is the reason most ships go down. "If the boat begins to ice up," Matsen says, "someone has to go out with a baseball bat and knock the ice off. Then you get in your survival suit and cry, vomit, hallucinate, and hold your vitals to protect them from the pounding."

"Whither are we being carried?" ancient seafarers to the Arctic were said to cry. "The day flees from us and uttermost nature closes in." That Norwegians regularly sailed in such storms impressed the Greeks. "They are more savage than Britons," goes a first-century report, "as they are both cannibals and omnivorous and consider it commendable to devour their deceased parents as well as openly to have commerce with not only other women, but also with their own mothers and sisters."

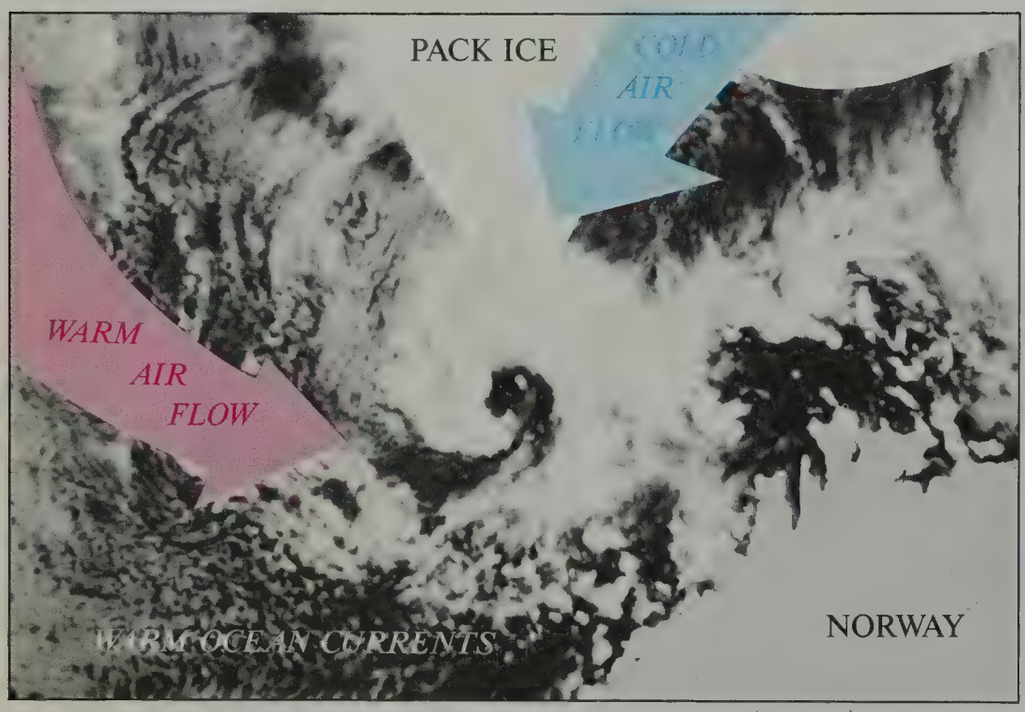
Norwegians have had more reason than most to fear the sudden storms. Fishing has been vital to their lives since at least the time of the Vikings. Fish feed in warm waters brought northward from the western Atlantic by the strong Norwegian Current, an offshoot of the Gulf Stream. For cod, the waters off the northern coast of Norway are its winter spawning grounds. Fishing these waters during the long arctic winter nights—in December and most of January there is no daylight at all—puts fishermen right in the path of the arctic hurricanes. In the fishing villages of the Lofoten coast in northern Norway, stories are told of a hundred vessels, carrying the men of an entire village, lost in a single blow.

Sailors on ships in Allied supply convoys in the embattled North Atlantic during World War II were suprised by how

The Formation of the Arctic Hurricane

Air temperatures over the pack ice can be -40°F. When winds from the north blow this air down over the open ocean, it meets up with air that's been heated up to 55°F by warm ocean currents. Where they meet is where arctic hurricanes form. The warm air is churned into the center of the cyclone, the cold air wraps around the outside. As in a tropical hurricane, there is an eye of the storm where the air is warm and relatively clear.

NOAA-7 Infrared Satellite Image



violently the hurricane-force storms could erupt, suddenly putting weather between themselves and the wolf packs of German submarines. "Before a storm, the seas were always calm and there was often fog," recalls Gus Krell, who sailed as a signalman on convoys through the Norwegian Sea. "When the fog lifted, the storm came in. There were lightning strikes all around the ship and driving snows. The waves were so strong they cracked the seams between the steel plates on the top decks, and water rushed in on our bunks. From the bridge I watched the bow rise eight stories in the air, then come down just as far. As the stern came up out of the water the screws turning in the air shook the ship so that it seemed as if it would tear apart." Men rushing to battle stations on icy decks were too often washed into the cold dark seas where they disappeared. In a January 1945 communiqué, Krell radioed his commodore's congratulations to all ships in the convoy: "The Arctic has knocked us about this time but under the good hand of Providence we have survived three gales and a hurricane in snow and darkness." ("After the storm we would shovel off the deck," says Krell, "add syrup to the snow and have ice cream.")

The commodore's intuition about the storm was right. Forty years later, satellite photographs confirmed the existence of arctic hurricanes. Infrared cameras pierced the overcast skies of the arctic night, and meteorologists saw spirals of swirling clouds, sixty to three hundred miles in diameter, wrapped around a distinct eye. Such cyclones had only been seen before from above tropical oceans. Now they saw them off the northern Pacific coast of the United States, off the Aleutian Islands of Alaska, and in the Bering Sea. These storms trailed clouds for eight hundred miles behind them. Over Nordic seas, where more satellites were focused, twelve to twenty-four hurricanes appeared each winter in the waters east of Greenland, surrounding Iceland, and in the Barents and Norwegian seas. These cyclones were more compact than tropical hurricanes and eluded ground-based weather stations. Their clouds and hurricane-force winds condensed in several hours (tropical hurricanes can take a week or more to develop), then swirled out over arctic seas at speeds of up to thirty knots, two to three times faster than most tropical storms.

Hurricanes are great natural engines. Using ocean water as fuel, they convert heat energy to wind energy. As a fan cools by increasing the evaporation of perspiration, winds over the tropical oceans evaporate the warm water, which then rises into the air as water vapor. As the wind speed increases, more water vapor is formed. When the air aloft is saturated, like the air above a pot of boiling water, the water

	Typical Arctic Hurricane	Typical Tropical Hurricane
Location	Northern latitudes: south of polar ice in the North Pacific Ocean, Bering Sea, Norwegian Sea, Barents Sea	Middle latitudes: in tropical seas in the Indian, Atlantic, and Pacific oceans
Time of Year	October to April	August to October
Air Temperature	−20° to 55°F	77°F
Speed of Development	12 to 24 hours	3 to 7 days
Diameter of Storm	60 to 300 miles	300 to 1,200 miles
Diameter of Eye	5 to 100 miles	5 to 100 miles
Wind Speed	50 to 100 miles per hour	75 to 180 miles per hour
Speed of Travel	30 miles per hour	10 to 15 miles per hour
Deepest Pressure	940 millibars	900 millibars
Height of Storm	5 miles	12 miles

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Cold air sweeps south from Alaska and passes over the mountainous coast of Kodiak, below, where it soon runs into air over the Pacific that has been warmed by the Alaska Current. The instability that results often spawns cyclones that West Coast fishermen know as big blows.

Steven Businger

condenses and forms clouds, releasing large amounts of energy in the form of heat. Heating of the upper air lowers its density and creates an area of deepening low pressure into which surrounding air rushes and swirls upward. The strength of wind gusts in hurricanes is directly related to the amount of heat being transferred from water vapor into the storm.

The eye of the hurricane is relatively calm, temperatures are warmer, and the sky clear. Warm air rising around this center creates great towering cumulonimbus clouds, which when saturated with rising water vapor, shed their moisture in great bursts of rain. As long as warm, moist air flows in toward the center of the storm and the ocean is warm enough to keep supplying the heat and water vapor, the hurricane will continue. The question for meteorologists, with evidence of arctic hurricanes in front of them, was what fueled a cyclonic storm in northern seas?

Kerry Emanuel, a professor of meteorology at the Massachusetts Institute of Technology, says that while surface winds over arctic waters pump water vapor into the air, the heat in the water vapor does not provide enough energy to fuel a hurricane. But if this energy were supplemented by another source of energy, the two combined might begin to get a storm going. That extra source of energy, says Emanuel, lies in the great difference between the temperature of the ocean waters in Nordic seas and the temperature of the air directly above. The temperature of the ocean currents can be as high as 65°F. The air temperature, influenced by winds off the polar ice, can be below zero. The

ocean, like a great radiator, warms the air above it and sends it up into the gathering storm. When gust measurements are made inside arctic hurricanes, the combined heat energy available to be converted to wind can be as great per square meter of sea surface as that of a tropical cyclone twice the size. The only thing preventing the arctic hurricane from gaining the same wind speeds as a tropical storm is its northern latitude. Nearer the poles, the earth's rotational force is stronger and counteracts the storm's rotation. Storm clouds, limited to the troposphere, can only reach about two-thirds the height of clouds nearer the equator.

Emanuel and other meteorologists believe there is more to the quick evolution of these storms. During the winter, the cracked and floating chunks of ice that are the leading edge of the thick, fast ice of the frozen Arctic drift southward. The temperatures over this pack ice range from freezing to forty below. To the south, influenced by the Norwegian Current, the water temperatures are above freezing and air temperatures range up to 55°F. When winds coming off the ice meet air warmed by the ocean currents, the dense cold air slides beneath the warm air. The warm air is forced higher and begins to condense. Where this happens the atmosphere becomes unstable. This is where arctic hurricanes occur. But how are they triggered?

Steven Businger, professor of meteorology at North Carolina State University, reviewed images made a day or two before the formation of an arctic hurricane. He looked with greatest interest at photos taken over the ice pack north of the open waters. Here is a kind of graveyard of old storms, the remains of large midlatitude storm systems that traveled north to the pole from the western Atlantic. In their final throes, these storms spin off small, swirling disturbances in the upper atmosphere. Businger found that when these small vortexes descend over the unstable air south of the ice, they can trigger cyclones around them. Once it has been triggered, the instability in the air, combined with recycled heat and the chaotic flow of cold and warm air currents, is what drives

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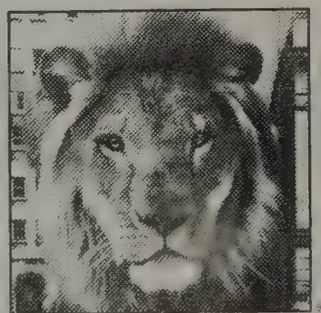

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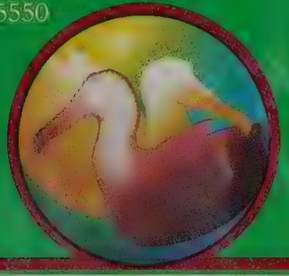

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In the midst of the storm there is lightning, thunder, and driving snow. Winds can be greater than seventy-five miles an hour; waves fifty feet and higher. For fishing vessels the greatest hazard is icing. When ocean spray freezes on the rigging the ship becomes top-heavy and likely to heel.

Don Kotts; Earth Images

an arctic hurricane to its sudden intensity.

Businger, tracking the cyclones by satellite in the Norwegian Sea, found they head quickly southeast from the ice edge toward the Norwegian coast, where without a source of heat or water vapor, they dissipate even more quickly than they began. On their way to the coast, cyclones pass over some of the most productive fishing grounds of the Norwegian Sea. A fishing boat or an oil rig there would have little advance warning. The weather would be deceptively calm, clear, dry, and warming, since the deepening storm with its rising winds is pulling in warm surface air. The first signs of trouble ahead would be north winds pushing up swells in the sea. By the time the barometer fell, it would be too late for a ship to turn and run out of the storm's path. On offshore oil

platforms, drilling and pumping rigs that are sunk into the sea floor must be disengaged during a storm—up to four hours' work. There is rarely a four-hour warning.

The storms form between far-flung weather stations. If spotted, they defy forecasters by passing between the grid points of even the most advanced computer models. This unpredictability increases their potential for destructiveness. Oil companies in Norway are so concerned by the phenomenon, they sponsored a three-year project to try to come up with a method of predicting the storms. Magne Lystad, who worked on the project with the Norwegian Meteorological Institute, says that while they have a better understanding of the storm's mechanics, they are still far from being able to predict them. Until they can, seafarers will still have to rely on baseball bats, the gods, or the good hand of Providence. □

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An Unfair Trade

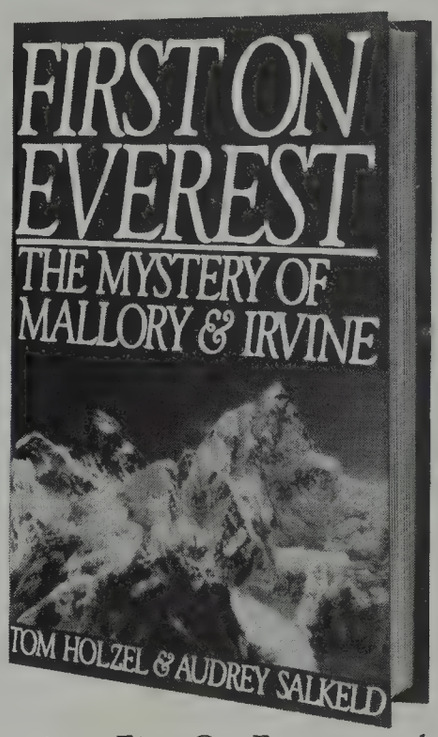
by Robert McC. Netting

How did people from one corner of the Old World manage to so quickly take root, flourish, and so thoroughly dominate North America, southern South America, Australia, and New Zealand? And how did the far-flung "Neo-Europes" they created become the major producers of Old World food crops and domestic animals, while multiplying their human populations fourteen times between 1750 and 1930? As the five-hundredth anniversary of Columbus's first voyage approaches, historian Alfred Crosby asks why the "Columbian exchange" (the title of his earlier, estimable book) should have been so unequal, why these European conquests should have been so overwhelming. The conventional textbook answers—firearms, iron confronting the Stone Age, large sailing ships, the quest for gold or pagan souls, the freedom from hunger or political domination that Europe could not give—reflect our faith in our own technology and culture, but they do not expose what Crosby calls "ecological imperialism," the biological factors he believes were fundamental to this extraordinary revolution.

Few scholars have the background in history, geography, geology, and demography—or the considerable self-confidence—needed to paint with broad strokes on a global canvas. The nineteenth-century ethnological penchant for mapping the diffusion of cultural traits or tracing the evolution of determined cultural stages has long been rejected as "speculative history" or racist conjecture. And more recent studies of acculturation have paid little attention to demography and local environment. But Crosby's natural history begins with the breakup of the supercontinent of Pangaea and the opening of the vast oceanic "seams" that separated biological provinces and initiated eons of evolutionary divergence. Flora and fauna could not move freely among the landmasses, and independent life forms developed in isolation for 180 or 200 million years. *Homo sapiens* was a relative latecomer to the Americas and Australia, an intruder who brought little to the new continents besides stone tools, fire, and the domestic dog. Crosby contends that the Old World's advantage was a distinctive ecosystem arising from neolithic plant and animal domestication and the coevolution of bread grains, grazing livestock, and plow agriculture in association with large, dense, sedentary human populations. Millennia of mutual adaptation and growth of animals, plants, and people beginning in the Near East forged a new ecosystem suited to the temperate climates and rich soils of more isolated parts of the earth and well equipped for competition with the native species. Riding along with the European carpetbaggers as unbidden, often invisible guests are what Crosby calls "portmanteau biota"—weeds, animal vermin, and disease pathogens. These organisms, along with European people, livestock, and food crops, effectively displaced or submerged many of the existing biological populations in those parts of the world that most resembled the home environment of the emigrés.

ECOLOGICAL IMPERIALISM: THE BIOLOGICAL EXPANSION OF EUROPE 900–1900, by Alfred W. Crosby. *Cambridge University Press, $22.95; 368 pp., illus.*

Germ warfare waged unwittingly by whites often preceded their advance from coast to hinterland and cleared their way more effectively than gunpowder. Native Americans lacked an immune system adjusted and tuned by heredity and experience to the European habitat, with its smallpox, measles, diphtheria, whooping cough, chicken pox, bubonic plague, malaria, typhoid fever, cholera, yellow fever, scarlet fever, amebic dysentery, and influenza. A relatively harmless European childhood disease could infect almost everyone in a "virgin soil epidemic" and kill half of them. To this day, even with modern medical treatment, an isolated community may lose 7 to 10 percent of its numbers to measles. Although the Amerindians in turn exported syphilis, yaws, hepatitis, and polio, these never stopped population growth in the Old World. The Guanches, who had settled the Canary Islands from the coast of Africa as early as 2000 B.C., were not overcome by the military technology or slave raiding of fifteenth-century Spanish and Portuguese, but a plague in 1495 all but exterminated them. During the same period, the European conquerors found the climate of the Canaries so healthful, they called their new possessions the Fortunate Isles. One of Crosby's more extended case studies follows the Maori of New Zealand as they adopt potatoes and pigs from Europeans, market their surpluses, buy axes and muskets, and convert to Christianity, only to lose half their population between 1840 and 1857 through infectious diseases. Darwin was told the melancholy native proverb that the Maori would go the way of the native rat, fly, and fern to extinction, and he recognized repeated



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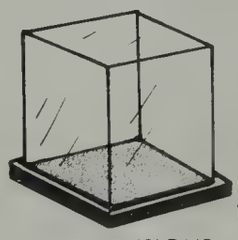

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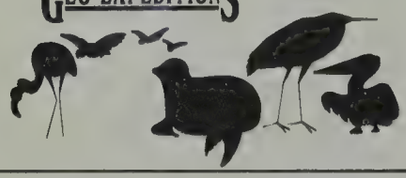

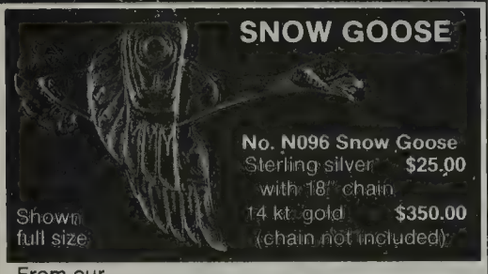

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An Episode of the Conquest of America *by Jan Mostaert, c. 1523*

biological replacement that not even he, a skilled naturalist, could have predicted.

When people migrate from a densely populated area into one that is more sparsely settled, they reduce their own risk of contracting communicable diseases and may carry with them infections unknown and possibly deadly to the locals. This process, called McNeill's law, after the historian of plagues and pestilence, may have helped the Israelites as they left the Nile Valley. Without an inkling of the bacteria and parasites they themselves harbored, Europeans were apt to see the hand of Providence in the sudden demise of their indigenous opponents. Crosby quotes John Winthrop, governor of the Massachusetts Bay Colony, as writing in 1634, "For the natives, they are neere all dead of small Poxe, so as the Lord hathe cleared our title to what we possess."

If viruses were a secret weapon in the Neo-Europes, the successes of European animals and weeds in their new niches were visibly effective in both engendering and domesticating the new wilderness. The large land animals of the Americas and Australia had died off at the end of the Pleistocene, perhaps owing to overkill by the first wave of invading hunter-gatherers. The "animal servants" of the modern invaders had the field to themselves. Pigs, reproducing rapidly and converting one-fifth of their omnivorous diet into edible meat, could thrive in frontier forests and even root for clams on beaches. Pork from feral pig was the most frequent protein source for early European settlers of Australasia and North America. Cattle were more efficient producers on grasslands, doubling their numbers in northern Mexico every fifteen years and forming wild herds reaching millions on the Argentine Pampa by 1700. The horse gave an obvious military advantage to the conquistadors. The few larger indigenous New World animals—dogs, llamas, guinea pigs, turkeys—were inferior sources of food, leather, fiber, and traction compared with the "self-replicating and world altering avalanche" of pigs, hens, sheep, cattle, goats, and horses from overseas. Inadvertently introduced animals competed with the human population for agricultural surpluses. The rats that disembarked with the Jamestown settlers so reduced the stores of food that they threatened the colony's existence only two years after its founding. The rabbits introduced into Australia were even worse. At the same time as the numbers of English sparrows and starlings mounted to the skies, the multitudes of native American passenger pigeons disappeared.

Although the new beasts could forage on native vegetation, their overgrazing, together with the resultant flooding and erosion, prepared the ground for a floral invasion. Hardy, opportunistic European weeds swept the prairies and fed the exotic livestock. The intruding grasses were already tolerant of bare soil, open sunlight, and the close cropping and heavy tread of the big quadrupeds. By the 1850s, 139 alien plants were growing wild in Australia. Fremont found that red-stemmed filaree had beaten him to California. White clover took over in New Zealand only when honeybee pollinators were imported. Again the trade was unequal; American ragweed and milkweed never gained a foothold in Europe.

Crosby's breezy, colorful narrative buoys the reader through a sea of historic observations without ever losing sight of his focus on biological expansion. Familiar facts, such as the voyages of Vasco da Gama and Magellan, become occasions for our discovery of counterintuitive triangular sailing routes, as the explorers mas-

ter the trade winds, the westerlies, and the monsoons to cross the trackless expanses of ocean. Earlier mariners lacking such ships and navigational aids may have gone as far but without making their landfalls into permanent habitations. Crosby also looks for causes of failed European transplantation in the Norse travels to Greenland and Vinland and in the Crusades to the Near East. The Vikings, who could occupy uninhabited Iceland, may have had their colonization doomed by the climate of Greenland and the indigenous inhabitants who outnumbered their small landing parties. Moreover, the Norse were so remote from the European heartland that they lacked the latest installments of epidemic disease to level their enemies. The Holy Land, on the other hand, had both large, permanent populations and its own virulent Old World illnesses, such as malaria, that decimated the North European Crusaders. In the same vein, it might have been instructive for Crosby to consider factors involved in non-European expansion, like the Islamic movement across North Africa and Iberia, the Indonesian migration to Madagascar, and the South Africa that did not (according to his classification) become a Neo-Europe.

It is perhaps unfortunate that "ecological imperialism" is so persistently differentiated in this volume from the less biological but more political and economic senses of imperialism. The Neo-Europes were, after all, peripheral colonies of European core states whose agriculture and trade followed distinctively capitalist models. Sociologist Immanuel Wallerstein's influential view of the modern world system or Eric Wolf's careful study of "the people without history" in the lands incorporated by the Europeans are nowhere in evidence. And Crosby skirts social and political conditions, such as slavery, that allowed pathogens to proliferate. Although ecology at its most inclusive can be everything, an orderly and intriguing exposition must needs leave a great deal out. Crosby's achievement isolates a set of factors—infectious diseases, domestic animals, and weeds—that gave Europeans a decisive advantage in certain environments of the globe. The biological bases of radically changing historical ecosystems must never be forgotten—and Crosby has made them intelligible as well as memorable.

Robert McC. Netting is professor of anthropology at the University of Arizona in Tucson. Netting's major research areas are cultural ecology, intensive agricultural systems, historical demography, and land tenure.

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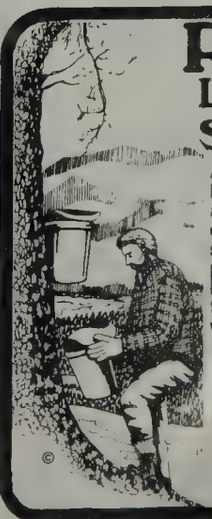

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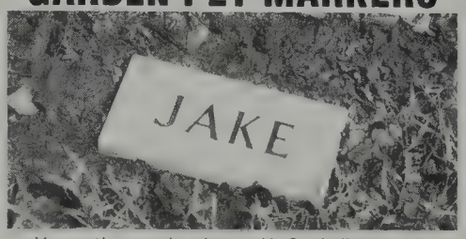

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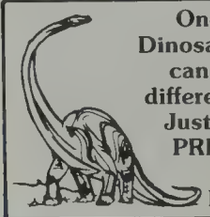

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At the American Museum

Origami

The *Origami Holiday Tree* is on display in the Rotunda for the fourteenth consecutive year. New this year are more than 1,000 silver stars forming a halo of mobiles over the tree. As in years past, the tree is decorated with origami models of animals past and present. As part of this year's display, the Museum is presenting a special exhibit on the development of origami. *Origami: Rooted in Ceremony* traces this art form from its beginnings in the Shinto religion of Japan, when origami models were hung in temple archways to ward off evil spirits, to its modern use as a symbol of good wishes when gift giving. Both the origami tree and exhibit will be on display through January.

Bach and Mozart Under the Stars

The Planetarium's third annual holiday concert will feature the music of Johann Sebastian Bach and Wolfgang Amadeus Mozart. Under the projected stars of a winter night, a live nine-piece ensemble will play to the accompaniment of flashing laser beams and other special effects on the Sky Theater dome. *Starlight Serenade* will take place on Monday, December 15, and Tuesday, December 16, at 7:00 and 9:00 P.M. Tickets are $7 for members and $10 for nonmembers. For more information call (212) 873-1327.

Adirondack Rock

According to Yngvar W. Isachsen, principal research scientist for the New York Geological Survey, one need not leave the earth to collect the kinds of

Fire Fountain at Pu'u O'o

The fire show began just hours after American Museum geologist George Harlow and his party of twenty-two arrived at Hawaii Volcanoes National Park. The group, on a Museum-sponsored Discovery Tour, had gone to see a volcano firsthand. Pu'u O'o is a secondary vent on the shield volcano Kilauea. It developed during the past few years as successive eruptions along the east rift of Kilauea formed a cone nearly five hundred feet above the park. It is highly active, erupting every twenty-two to twenty-eight days.

On the evening of February 22, the eruption began. For more than eight hours, the volcano spewed molten lava more than 1,000 feet into the air. The Museum group got its first glimpse of a live volcano at nine o'clock, and for more than an hour they watched the fire fountain from a comfortable distance of seven miles, where Beverly Harper took this picture with a 500-mm lens. Fortunately for the visitors, they had a clear view of the volcano. Usually, Harlow says, a low cloud cover develops in the evening, obscuring the crater. The size of the plume was also remarkable. Often, Harlow says, it is less than three hundred feet and sometimes there is no fountain at all. At those times, he says, the lava simply oozes out of the cracks on the side of the volcano, overflowing "like a caldron of boiling lava."—M. S.

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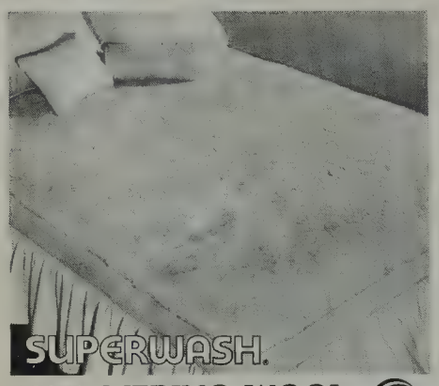

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rocks found on the moon; they may be found in the high peaks of the Adirondack Mountains. On Tuesday, December 2, at 7:30 P.M. in the Main Auditorium, Isachsen will present an illustrated program tracing the geological history of the region and explain its geological curiosities, such as the first fossil found in the mountains. This program is free for members and $4 for nonmembers. For more information call (212) 873-1327.

Kwanzaa

Kwanzaa (Swahili for first fruit) is an original African-American holiday celebrated each year from December 26 to January 1. Founded in 1966 by Mualana Karenga, a noted black studies scholar, Kwanzaa is derived from centuries-old African values. The Department of Education, in association with the New York Urban Coalition, will observe Kwanzaa with a series of programs including concerts, films, and workshops exploring African culture. For a complete schedule of events call (212) 873-1300, ext. 514.

Afro-Cuban Jazz

New Yor-Uba is a jazz ensemble that specializes in the music of the Yoruba, an African people brought to the New World by the slave trade. In Cuba, Yoruba worship—ecstatic drumming, dancing, and singing—evolved into Santería and eventually made its way into popular music, first in Cuba and later in the United States. On Wednesday, December 10, at 7:30 P.M. in the Main Auditorium, New Yor-Uba will perform music that combines jazz with traditional Afro-Cuban rhythms. Tickets are $5 for members and $6 for nonmembers. For more information call (212) 873-1300, ext. 514.

Alzheimer's Story

Alois Alzheimer, a German physician, published the first paper on the disease that bears his name in 1906. Today, Alzheimer's disease affects more than two million Americans. *An Alzheimer's Story*, a videotaped documentary, depicts the deterioration of an Alzheimer's victim over two years. It focuses on her family's suffering as well as her own and the eventual need to institutionalize her. *An Alzheimer's Story* premières on Saturday, December 13, at 1:00 P.M. in the Kaufmann Theater, followed by a panel discussion on the personal, sociological, and medical aspects of this illness. Panelists include Kenneth Rosenberg, one of the documentary's producers, Peter Davies, a researcher on Alzheimer's at Albert Einstein College of Medicine, and anthropologist Malcolm Arth. Tickets are $13 for members and $15 for nonmembers. For information call (212) 873-7507.

A Toot for Tots

The Bloomingdale Chamber Orchestra will perform classical music for children on Sunday, December 14, at 3:00 P.M. in the Kaufmann Theater. The concert, entitled *Who Gives a Toot*, is free with Museum admission. For more information call (212) 873-1300, ext. 566.

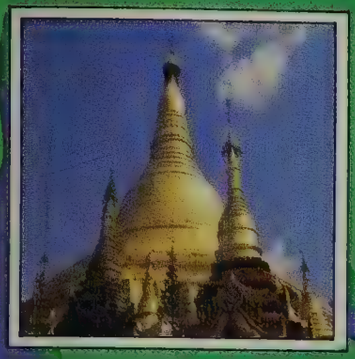
Culture of the Red Ocher

Five thousand years before the first Eskimos came to Labrador, the Red Ocher, a people whose culture is known to archeologists as Maritime Archaic, occupied the northeast coast of North America. When they disappeared about 3,500 years ago, their culture had reached a stage of elaborate development, as represented by complex burial mounds, chipped-stone tools, and indications of trade networks that extended from northern Labrador to southern New England. A documentary film, *Red Paint: The Lost Sea People of Maine*, which examines the background of these people and recent discoveries about them, including the possibility of European contact by sea, will première on Sunday, December 7, at 1:00 P.M. in the Kaufmann Theater. After the screening, a panel consisting of William Fitzhugh, curator of arctic anthropology at the Smithsonian, Bruce Bourque, Maine State Archeologist at the Maine State Museum, and James Tuck, professor of archeology at Memorial University, St. John's, Newfoundland, will discuss questions raised by the film. Tickets are $13 for members and $15 for nonmembers. For information call (212) 873-7507.

The Star of Christmas

This holiday Sky Show, at the Planetarium through January 4, takes viewers back in time nearly 2,000 years to view the skies of the first Christmas. The show explores the question "What was the 'star' that led the Wise Men to Bethlehem?" and shows how scientists, historians, and theologians have worked together to find possible answers. For further information call the Planetarium at (212) 873-8828.

American Museum of Natural History



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Evening Holdovers

by Thomas D. Nicholson

Mars and Jupiter are still holding out in the evening sky, nicely placed in the southwest in the early evening to balance the bright winter stars rising in the east. Last September and October, all the planets were evening stars; now only these two and Neptune remain. The others have moved to the right (west) of the sun to become morning objects, and at least one of them, Venus, should be visible as a morning star this month.

The two evening planets, Mars and Jupiter, are close together all month. The brightness of Jupiter, outshining everything else but the moon, makes it an easy target from late twilight until it disappears in the west before midnight. Mars is now fading rapidly as it moves almost directly away from the earth, but it is still in the range of first magnitude and is the only bright object near Jupiter.

Venus is at maximum morning brilliancy in early December and almost at its greatest elongation (separation) from the sun at the end of the month. Both times are favorable for viewing, but the southerly location of the planet doesn't help. It should be visible in the southeast at about dawn from midmonth on, and will be easily seen late in the month with the crescent moon nearby.

As noted in the calendar that follows, the moon occults Antares twice this month (on the 1st and the 29th). The two events occur about twenty-seven and a half days apart. This is the sidereal month, the interval during which the moon moves completely around the earth. There is a new moon on the 1st as well, and the next new moon is on December 31, very nearly twenty-nine and a half days later. This is the synodic month (interval from new moon to new moon or full moon to full moon), during which the moon returns to the same position relative to the sun.

Events in the calendar below are given in local time unless otherwise indicated.

December 1: New moon is at 11:43 A.M., EST. The moon occults Antares at about the same time, while they are above the horizon over North America, but daylight hides the event.

December 2: Perigee moon (nearest the earth) is eighteen hours after new moon, and its effect will strengthen the spring tides that come with a new moon.

December 4: The young crescent moon will appear at twilight and set shortly thereafter. Saturn is in line with the sun (conjunction) and enters the morning sky.

December 5–7: The crescent moon stays up later and becomes brighter each night, but not enough to interfere with our view of Jupiter and Mars, which are above and to its left after darkness begins. It advances on the two planets nightly, catching up with Mars on the 7th, when the two planets and the crescent moon make a handsome sight.

December 8: If you missed them last night, look for the moon, Jupiter, and Mars after sundown tonight when the moon is past both planets. First-quarter moon is at 3:01 A.M., EST.

December 11: Venus is at its greatest brilliancy in the morning sky.

December 13–15: The waxing moon fattens and brightens as it moves into and through Taurus on the way to full phase. The stars of the Pleiades cluster are close above it on the 13th, and Aldebaran, the brightest star in Taurus, is easily visible in the glow of the moon's brightness on all these nights.

December 16: Full moon is at 2:04 A.M., EST. By twilight it has moved to Gemini, about midway between bright Aldebaran to its right and the twin stars Pollux and Castor to its left.

December 18: The moon moves into Cancer before it comes into line with Pollux and Castor. Look early tonight, before it moves off-line from the stars to the east (left).

December 19: Four planets are in conjunction with one another today, but two by two, not all together. Mars finally

Celestial Events

catches Jupiter at about 2:00 A.M., EST, and will be seen very close to Jupiter's left (east). Mercury and Saturn are in line with one another at 10:00 A.M., EST, but too close to the sun to be seen.

December 20–22: Leo is a spring constellation, but if you stay up after 10:00 P.M. these nights, it will be rising in the east and the moon can help in finding it. The moon is right above the Lion's brightest star, Regulus, on the 21st.

December 21: The sun arrives at the winter solstice in the constellation Sagittarius at 11:02 P.M., EST, and winter begins in the Northern Hemisphere. The duration of daylight is the shortest of the year today, although the earliest sunset took place December 8th and the latest sunrise will be on January 5th.

December 23–24: Moonrise is at approximately 11:30 P.M. on the 23rd, almost when the moon is at the autumnal equinox in Virgo, one-quarter of the way around the sky to the right (west) of the sun's position at the winter solstice. Last-quarter moon, also in Virgo, is at 4:17 A.M., EST, on the 24th.

December 26–27: You should be able to find very bright Venus below the rising crescent moon at about dawn on both mornings. The moon will be in conjunction with Venus late in the evening of the 27th.

December 28–29: The moon is in conjunction with Antares and Saturn on the 29th. Venus should be visible both mornings, but Antares and Saturn are lower, closer to the sun, dimmer, and rise in a brighter sky.

December 30: Another perigee moon occurs at 6:00 P.M., EST; new moon is at 10:10 P.M., EST. The effect of perigee will add to the spring tidal range, substantially increasing the high tides that will occur tomorrow.

Editor's Note: The Sky Map in the October issue shows the evening constellations and stars for this month and gives the dates and times for use.

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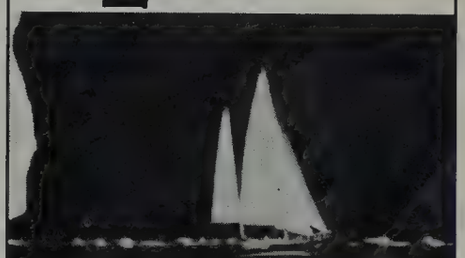

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A Star Is Born

Exotic fruits can substitute for dismal mainstream fare

by Raymond Sokolov

When a new fruit swims into our ken, as it were, we ought to feel gratitude and joy. For me, the largely unheralded advent of the star fruit (a k a carambola a k a *Averrhoa carambola*) has brought mainly disappointment and anger.

The disappointment came on those several occasions when I paid top dollar for one of these highly attractive yellow, almost seedless fruits. Full of anticipation, I cut a crosswise slice into the waxy torpedo with its five deep longitudinal grooves. The slice fell away in a stellar pentagonal wafer. Then I bit into it and puckered.

Not all star fruits are sour. After discussing this matter with my favorite fruit cicerone, Elizabeth Schneider, I learned that there are basically two sorts of carambola, one sour and one sweet. But try to tell which is which. In her encyclopedic yet genial new handbook, *Uncommon Fruits and Vegetables: A Commonsense Guide* (Harper and Row), Schneider gives the following reasonable advice: "If carambolas are not marked 'tart' or 'sweet,' you should at least try to convince your fruit man of the value of taste tests for sales. Ask him to sample the fruits so that he'll understand the difference. If all else fails, figure that most tart varieties have very narrow ribs, while the sweet yellow varieties have thick, fleshy ones. The two white varieties marketed are sweet."

I have tried these dodges with limited success. My local "fruit man" is in fact a Korean teen-age girl whose response to my earnest requests for truth-in-carambola are met with giggles, at first, and then with the cries of alarm she has learned to emit when an incomprehensible and persistent customer harasses her. Burly Korean men swiftly come to her rescue; they are not helpful either. How, they ask me, can I expect them to know about the niceties of star fruits, when they must also deal with the clementines and tomatillos and monsteras and other novelties flooding the market they try so industriously to serve?

It is this maddeningly burgeoning world of atemoyas and tamarillos and feijoas (as well as the lesser known, if more traditional vegetables and fruits, such as favas and quince) that Schneider has worked so hard to fathom and to explicate. As her title declares, she aims to make the unfamiliar comprehensible, to provide useful annotations to the novelties mysteriously populating our better fruit bins. This is important work for its own sake, but it is also a sign of a larger, undocumented process going on in advanced societies around the world. The traditional larder is being enlarged by an innovative agriculture and a global system of food transport that is bringing the exotic to our doorstep and transmuting it into the mundane.

The process is moving so quickly that any curious person requires a guide in order to decode his corner market. On the one hand, this is a good thing—variety is the spice of life, and so forth. Yet there is a sense in which our modern cornucopia is an emblem of decadence and decline. We can fly fancy fruit from New Zealand to Manhattan's Upper West Side, but we

Photographs by James Joern

In New York it's easier to find a New Zealand kiwi than a ripe apricot. Here, exotic and traditional produce arrives at Hunts Point Market in the Bronx.

JOHN GOULD'S

EXOTIC BIRDS OF ASIA

A Universe 87 Calendar
American Museum of Natural History

Fiery-tailed Sun-bird

February

sun	mon	tue	wed	thu	fri	sat
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

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cannot get decent apricots. There are many examples of this paradox, where a traditional food is vanishing or reaches the market only in inferior form. The reasons for this spreading phenomenon are complex, but they amount to the same thing. Traditional produce grown for the mass market must be engineered so as to survive a long trip looking beautiful. Biology is distorted in the service of cosmetology. Fruit is picked green so as to be sturdy.

The apricot does not ripen properly under these circumstances. As a result, sensible people do not buy apricots in New York except out of perverse nostalgia. I suspect that many readers will think I am exaggerating here, but they haven't eaten a tree-ripened apricot recently. Our ancient tree bore a few fruits this year; each one was a miracle. But I know from experience that our tree is not unusually wonderful. Anyone who buys apricots from a stand in or around Santa Fe will see that properly ripened apricots are routinely fabulous. But they don't travel as a mass-market fruit.

Ergo, people like me avoid them and turn to "new" fruits that have not yet been corrupted by greed or bioengineering. Novelty fruits also tend to be grown on a small scale by people interested in establishing that fruit's reputation. They do a better job than, say, hopelessly cynical tomato operators catering to a vast, if depraved, market of people actively seeking firm so-called slicing tomatoes.

Some specialty produce is flown to market. It costs more than apples held in coolers for six months but arrives at market in optimal eating condition. But once the fruit becomes a commercial success as an elite item, its producers look for ways to enlarge sales. New varieties are hybridized; new methods of harvest and storage devised. This is not always a bad thing. Some novelty fruits have made the transition from exotic to normal without a squeak. Both the avocado and the mango are good "modern" fruits. They do not suffer from being picked green.

The star fruit looks as if it is also naturally adapted to modern life. According to Schneider, fully ripe, room-perfuming star fruits will keep for two weeks in the refrigerator. Like the kiwi and the passion fruit and many of the other newcomers, they are much less fragile than more traditional western fruits. We can only hope that the mad geniuses of plant science will not find ways of transmogrifying their genes so as to destroy their taste appeal. For the time being, novelty fruits and vegetables tend to be produced rationally and therefore retain the flavor and appeal that recommended them to growers in the first place. This is one reason why astute *nouvelle cuisine* chefs have battened on them. Yes, they are glamorous and exotic, but they are also a means of circumventing dismal mainstream horticulture.

Perhaps the most interesting side to this wave of novelty at fruiterers and in restaurants is not that it is a logical response to degraded traditional produce, but that appreciable numbers of people are persuaded by this logic to change ingrained habits and to alter their diet. No one can calculate with precision or certainty just how much the traditional American diet has changed since World War II. But all evidence indicates that an enormous shift has occurred for a complex of reasons, ranging from fear of cholesterol to the growth of connoisseurship in a well-traveled, well-heeled elite conditioned to novelty and change in all areas of life.

There is one group, however, that has resisted these pressures. Its members have devoted their lives in most ways to freezing time in its path. And the very emblem of their pure conservatism is their diet. I refer to orthodox Jews.

Their table is the symbol of their identity. Indeed, the central, practical guide to correct orthodox Jewish practice is called *Prepared Table*. So the last place you would expect to find a star fruit in pride of place would be at an orthodox meal. And yet, why not? The rules of kashruth do

Star fruit, also known as carambola

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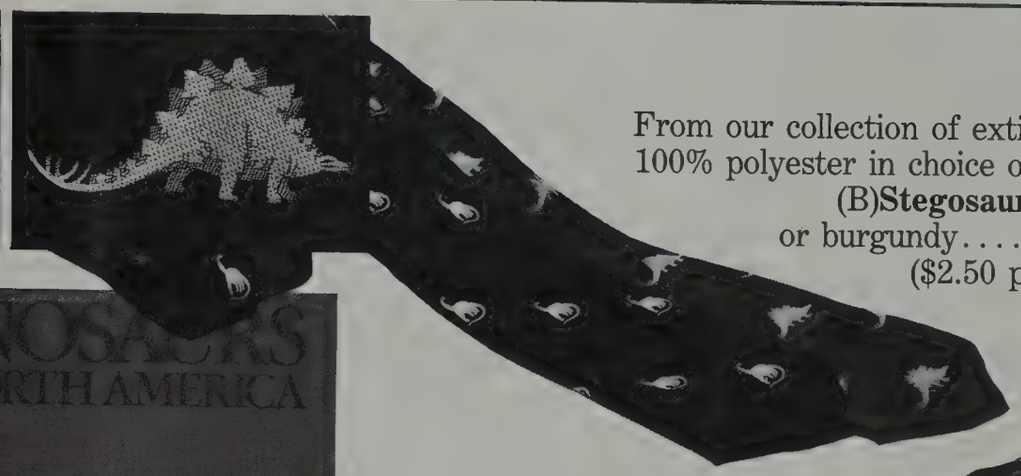

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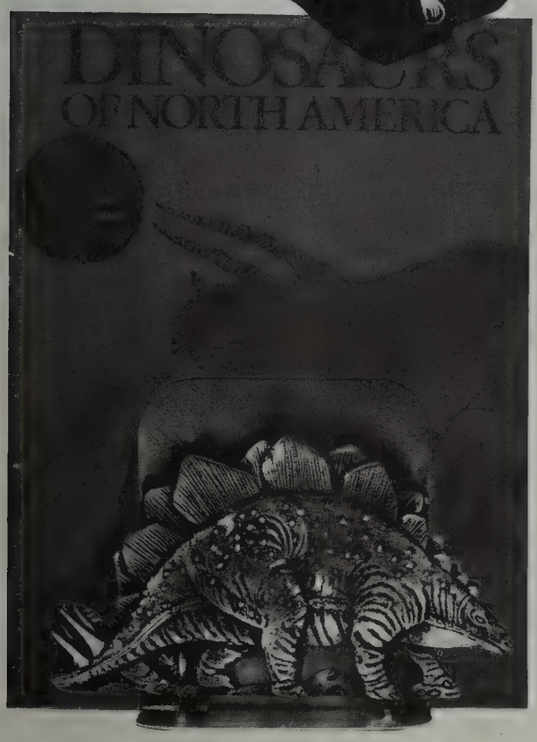

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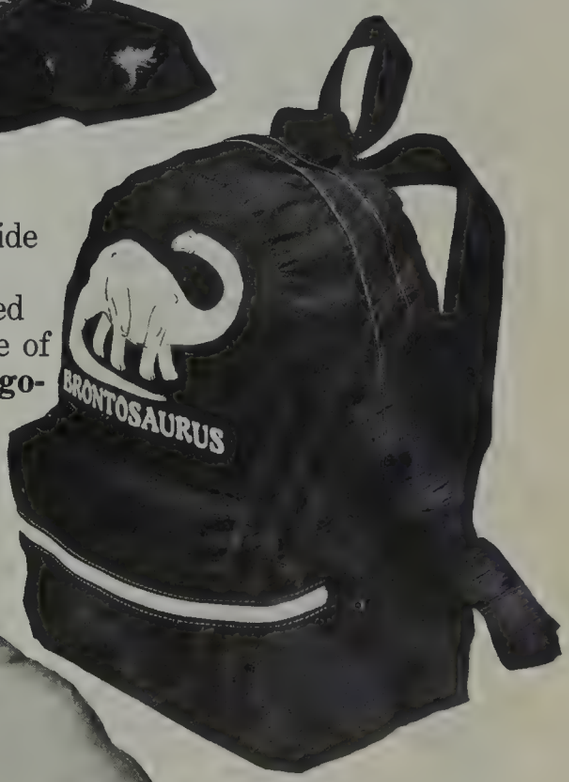

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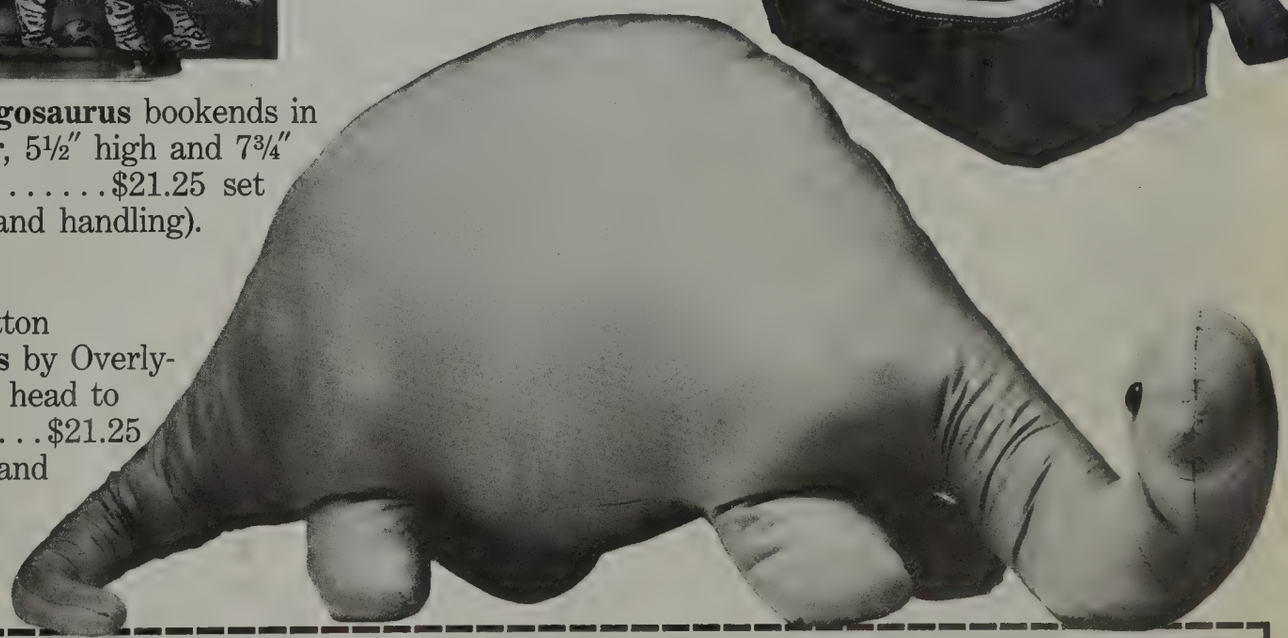

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proscribe certain ingredients and certain combinations, and the prohibition against mixing meat and milk has even inspired the alteration of certain recipes so as to make them kosher. But kashruth is notably silent about innovation. There is no canonical body of Jewish traditional recipes. And what we think of in New York as Jewish food is really an amalgam of Eastern European dishes kosherized and then codified by use in the Jewish liturgical calendar. Entirely observant Jews from the Near East do not normally eat flanken and borsht at home. And they find the Ashkenazic (European Jewish) diet as foreign as American Jews of Ashkenazic heritage find theirs. Paul Levy, the Kentuckian food editor of the *London Observer*, once said of Claudia Roden, a Jewish refugee from Cairo who is best known for her book on Middle Eastern cookery: "Claudia's idea of Jewish food is stuffed grape leaves."

Levy assumed everyone would see the absurdity of Roden's claim. Well, we did and we didn't. The serious Jewish table is, by definition, a place where tradition is always at issue, because the purpose of kashruth is to define Jewish life. And so it is a bolder act than it might seem at first for a non-Jewish woman to publish a kosher cookbook intended to bring the spirit of the *nouvelle cuisine* to pious tables.

Colette Rossant is, of course, a gifted and original cook with a broad background in the food of three continents. Almost anyone might profit by looking at the recipes she has developed for *New Kosher Cooking*. Taking the orthodox point of view, moreover, it is hard to see why a pious Jewish cook would not want to try such modern ideas as spaghetti squash soup or, indeed, baked tilefish with star fruit. There are also kosher adaptations of exotic recipes (yakitori of lamb and chicken).

Many modern orthodox cooks will be delighted to see how wide the gates of kashruth really are. Although even Rossant has not been able to solve the problem of producing tasty baked goods for a meat meal, she has achieved much else, including the conversion of the star fruit (see recipe below).

Raymond Sokolov is a writer whose special interests are the history and preparation of food.

Carambola Ice

(From *Uncommon Fruits and Vegetables: A Commonsense Guide*, by Elizabeth Schneider, Harper and Row)

1¼ pounds fragrant medium-sweet carambolas (select deep-colored ones if you have a choice), rinsed
1¼ cups sugar

1. Set aside ¼ pound carambolas (preferably 2 small fruits) and cut remainder into fine dice.
2. Combine 1 cup sugar and 1¾ cups water in saucepan; boil for 2 minutes. Remove from heat and stir in diced fruit.
3. Purée in blender or processor to a smooth texture; press through a fine-meshed sieve. Let cool slightly, then chill thoroughly.
4. Pour into can of ice cream maker. Freeze according to manufacturer's directions.
5. When frozen, scoop into a container and allow to mellow in the freezer for a few hours or more.
6. Shave brownish skins from ribs of remaining carambolas; cut fruit across into ⅛- to ¼-inch slices. Combine remaining ¼ cup sugar and 1 tablespoon water in a nonaluminum skillet, heat to boiling, and add the fruit slices in a single layer. Cook on high heat for about 10 seconds. Turn the slices and cook 10 to 15 seconds, to glaze slightly. With a slotted spoon transfer to a dish; cool and chill.
7. To serve, soften ice for about ½ hour in refrigerator. Place a tidy scoop on each chilled desert plate and set a few slices of glazed carambola alongside.

Yield: 4 servings
(about 3 cups carambola ice)

Baked Tilefish with Star Fruit

(Slightly adapted from *New Kosher Cooking*, by Colette Rossant, Arbor House)

4 thick tilefish steaks
Salt
Freshly ground black pepper
½ cup water
2 tablespoons dark soy sauce or low-sodium soy sauce
¼ teaspoon sesame oil
2 slightly sour star fruit, thinly sliced crosswise
2 tablespoons chopped parsley
2 lemons, cut into wedges

1. Preheat oven to 400 degrees.
2. Wipe the fish steaks with paper towels and arrange them in a baking dish. Sprinkle with salt and pepper to taste.
3. In a bowl, mix together the water, soy sauce, and sesame oil. Pour over the fish and bake for 8 minutes. Scatter the star fruit slices over the fish and bake for 6 minutes more.
4. Remove the fish to a serving platter. Arrange the sliced star fruit on and around the fish, pour some of the sauce over the fish, sprinkle with the chopped parsley, and serve with lemon wedges.

Yield: 4 servings

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Islands of Japan

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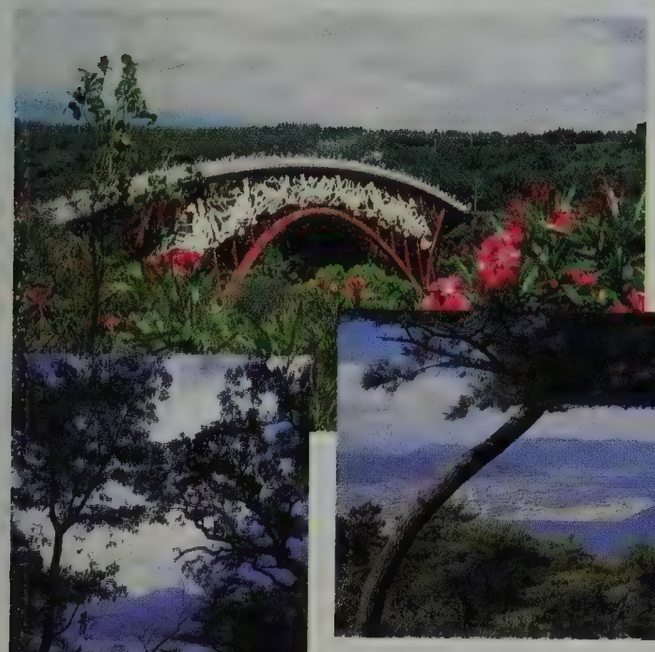

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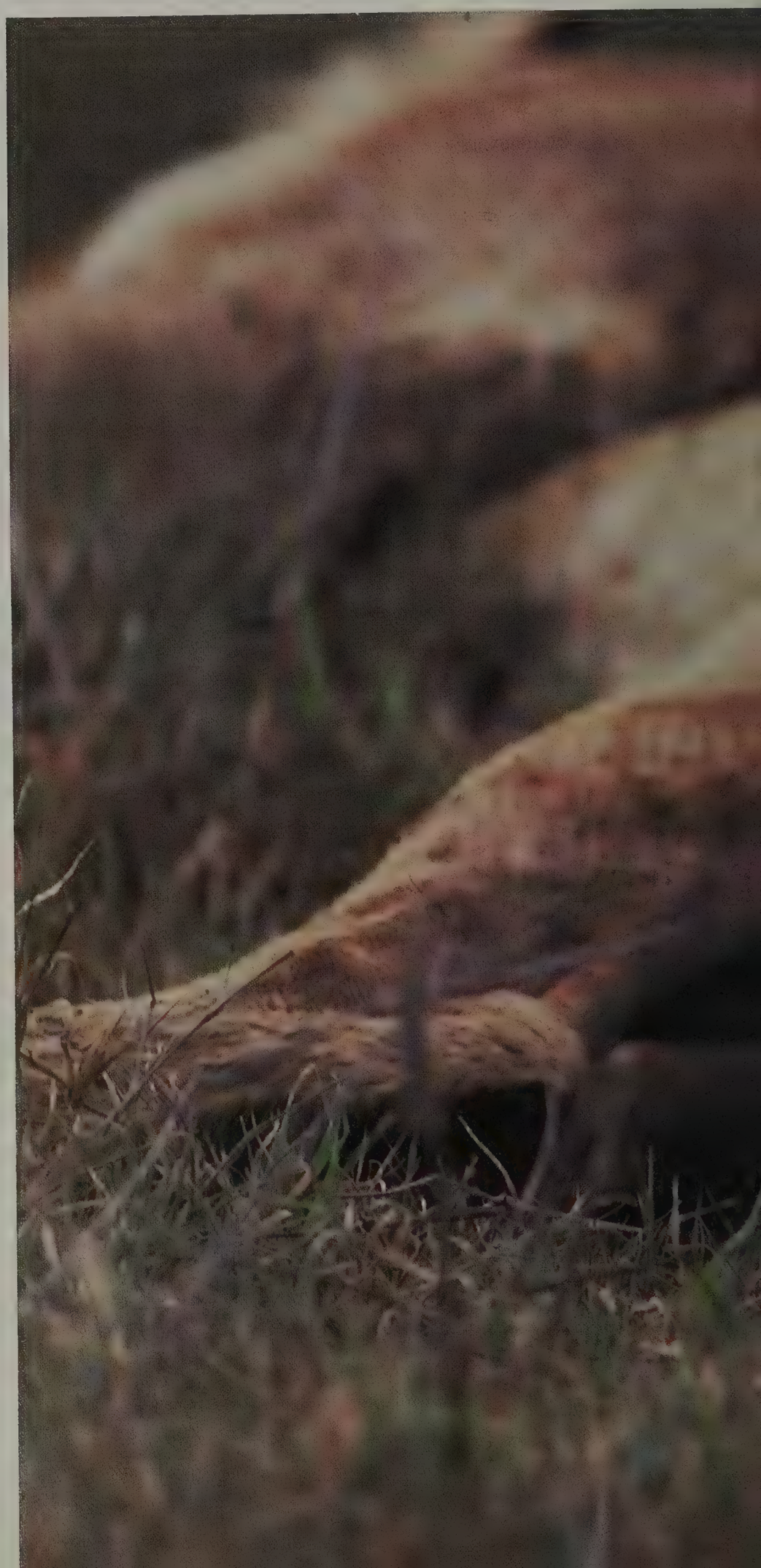
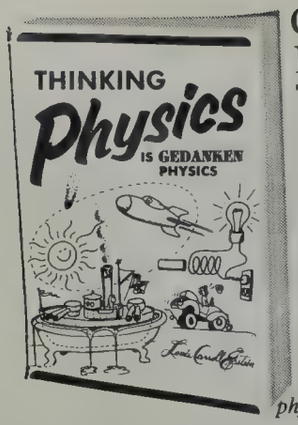
The Play's the Thing

The lioness was trying to catch forty winks on the soft grass of the Ngorongoro Crater, an enormous, unflooded caldera in Tanzania, when her progeny decided to intervene. The warm, wet February afternoon had brought out the bugs, and the semiconscious lioness was twitching her tail to keep them away. Like a kitten fascinated by a length of yarn, her cub watched the motion—and sprang. Chomp! Undisturbed, the mother flicked her tail away. Again the cub pounced, and again its mother snatched away her tail. And again, and again, spring-chomp-swish, spring-chomp-swish, through the lazy African afternoon.

In addition to being a source of amusement, such play helps the young lion's eye–paw coordination and trains it for the later—and decidedly unplayful—business of hunting. Playing is a simulation of adult activities. After hopping back and forth after mother's tail, a lion is ready to attack small game. This cub spent the afternoon stalking mamma in the heat of day, blissfully unaware of the utilitarian purpose of its frolic.—*Charles C. Mann*

Photograph
by Robert Caputo





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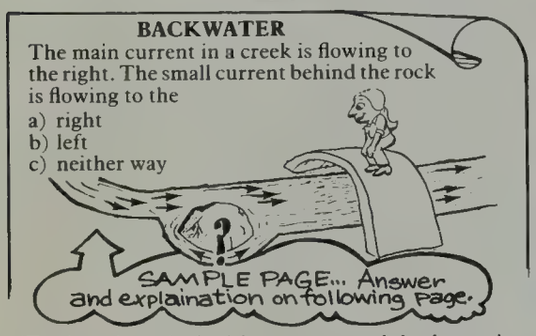
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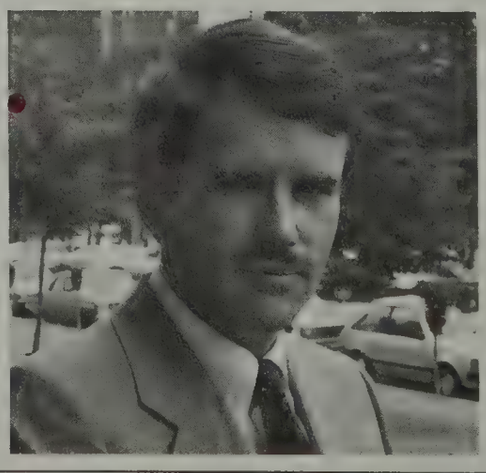
Authors

Because much of his previous archeological fieldwork had been at rock-shelters and caves in western North America, in 1973 **James M. Adovasio** (page 20) sought out a similar site in southwestern Pennsylvania as a summer field school for his students at the University of Pittsburgh. In an example of scientific serendipity, Meadowcroft, as the site is called, turned out to be unexpectedly ancient. Adovasio is professor of anthropology and professor of geology and planetary sciences at the University of Pittsburgh. Coauthor **Ronald C. Carlisle** (below), who has done background historical research on the site and its environs since 1976, is now a research assistant professor of anthropology at the same institution. For additional details about Meadowcroft Rock-shelter, readers may consult the chapter by J.M. Adovasio et al. in *Early Man in the New World*, edited by Richard Shutler, Jr. (Beverly Hills: Sage, 1983).



Lewis Hurxthal (page 34) has beer keen on wildlife since his childhood, bu a trip to Africa as an adult led him t leave his home and laboratory work i Boston and embark on a more adventur ous route: "The first serious plan didn' form until I saw ostriches on a tri through southern Ethiopia," he said "About a year later, I registered at th University of Nairobi and began m fieldwork on ostrich ecology." Hurxtha received his doctorate in zoology i 1979, after conducting research on os trich breeding systems in Nairobi Na tional Park and Amboseli Nationa Park, both in Kenya. In 1979, his wor was featured on a BBC television film "The Impossible Bird." Hurxthal, hi wife, and daughter now make their hom

in Botswana, where he is the principal o a training school for game ranger Readers planning a trip to Africa ma wish to consult John G. Williams's *Field Guide to the National Parks o East Africa* (London: Collins, 1981) Armchair travelers can read more abou the ostrich in Norman Myers's *Interna tional Wildlife* article, "Big Bird Turn It On" (March/April 1979).

In this issue, **Susan Mopper** and **Thomas Whitham** (page 42) describe their ongoing work with the piñon pines of Sunset Crater in Arizona. Between them they have investigated plant cloning, plant resistance to herbivory, and the effect of host plants on insect mating systems and sex ratios. Whitham, an associate professor at Northern Arizona University, holds a doctorate in ecology and evolutionary biology from the University of Utah. His photography has been exhibited in several one-man shows. Mopper, who earned her master's degree from Florida State University in Tallahassee, served for two years in the Peace Corps in El Salvador as a plant–insect cataloger. A fan of outdoor sports and new wave music, she will receive her doctorate early next year from Northern Arizona University. For further reading she suggests *The Piñon Pine*, by Harriette and Ronald M. Lanner (Reno: University of Nevada Press, 1981).

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